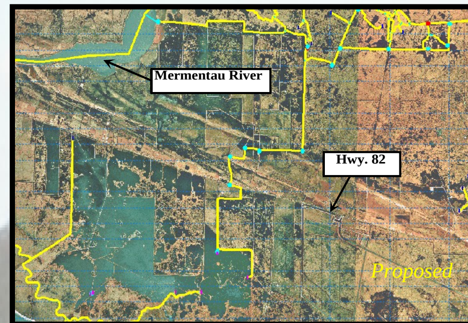
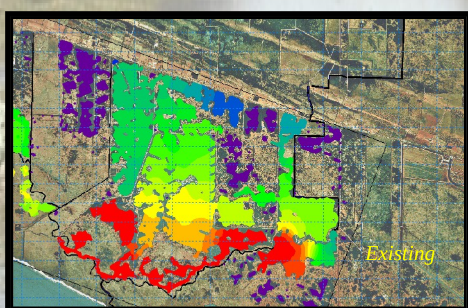
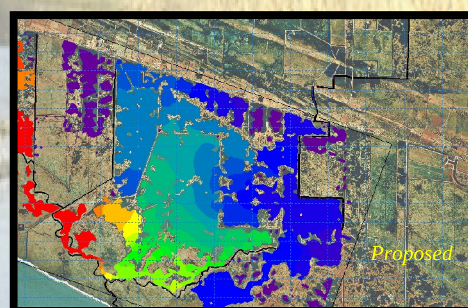
HYDRODYNAMIC MODELING

of the

LITTLE PECAN BAYOU HYDROLOGIC RESTORATION PROJECT (ME-17)







December 2005

Submitted By:

C.H. Fenstermaker & Associates, Inc

Civil Engineers *Environmental Consultants* *Land Surveyors*

Lafayette, LA *Baton Rouge, LA* *New Orleans, LA* *Houston, TX*

www.fenstermaker.com

TABLE OF CONTENTS

TABLE OF CONTENTS
(Continued)

Report Authors:

Ehab A. Meselhe PhD. P.E.
Senior Hydraulic Engineer

Dax A. Douet, P.E
Project Manager

Karim Kheiashy MS., E.I.
Hydraulic Modeler

C.H. Fenstermaker & Associates, Inc.

Lafayette • Houston • New Orleans • Baton Rouge

The Little Pecan Bayou Hydrologic Restoration Project (ME-17) is a Priority Project List (PPL) 9 Coastal Wetlands Planning, Protection and Restoration Act (CWPPRA) Project located west of the Rockefeller State Wildlife Refuge on the eastern end of the Grand Chenier ridge, approximately ten miles east of the community of Grand Chenier, within the Mermentau Basin in Cameron Parish, Louisiana. It is bounded on the west by the Mermentau River, on the south by the Gulf shoreline, on the east by Superior Canal, and on the north by Little Pecan Bayou.

The project area includes existing features that affect the hydrology of the project study area. These features include the elevated roadbed of LA Hwy. 82, canals, levees, plugs, and existing water control structures in Little Pecan Bayou and the surrounding bayous. These features prevent or impede fresh water flow from north to south i.e. to the unmanaged marshes south of LA Hwy. 82.

In order to assess the impact of the proposed project features both the Louisiana Department of Natural Resources and the Natural Resource Conservation Service have proposed using a hydrodynamic and salinity numerical model to study the impact of conceptual project features on the hydrology of the area. The model will be used to address two main goals set forth by the government agencies. These goals are to:

- Introduce fresh water to marsh areas south of Highway 82 especially in the brackish marshes to the south, thereby reducing salinities and lessen salinity spikes.
- Improve marsh productivity, reduce marsh loss, and increase submerged aquatic vegetation within the project limits.

The numerical model MIKE FLOOD was set up and then calibrated and validated for the existing hydrologic conditions of the project area. MIKE FLOOD is a dynamically coupled one and two-dimensional models. It allows for a dynamic interaction between channel and sheet flows. After the model was calibrated and validated, a direct comparison of the “Base Run (Existing Conditions)” and the “Conceptual Design Run (with proposed project features)” was performed. The model provided information regarding salinity and water level fluctuations, velocities, and discharges throughout the project area. The salinity transport was computed through an Advection Dispersion (AD) module, which was dynamically coupled with the hydrodynamic module. The final results of the model for the hydrodynamic and salinity were displayed through time series graphical plots, animations, and contour map illustrations.

Through various alterations with the project’s proposed conceptual features, two final freshwater introduction canal alignments, along with proposed hydraulic structures, were analyzed and presented in this report in Chapters Two and Three. Each of the two proposed alignments lowered salinity levels in the order of 2.5-3.5 parts per thousand, and raised water levels in the order of 0.2-0.3 feet in the selected target marsh areas south of LA Hwy. 82. The model was able to demonstrate that both alignments, along with the proposed structures, were able to satisfy the goals of the project. Since both alignments yielded roughly the same hydrodynamic and salinity results, other logistical considerations (land rights, construction cost, time to construct, etc.) should be considered when selecting the final alignment to be implemented in the field.

I. CHAPTER ONE

1.1 PROJECT BACKGROUND

The Little Pecan Bayou Hydrologic Restoration Project (ME-17) is a PPL 9 Coastal Wetlands, Planning, Protection and Restoration Act (CWPPRA) project located west of the Rockefeller State Wildlife Refuge on the eastern end of the Grand Chenier ridge, approximately ten miles east of the community of Grand Chenier, within the Mermentau Basin in Cameron Parish, Louisiana. It is bounded on the west by the Mermentau River, on the south by the Gulf shoreline, on the east by Superior Canal, and on the north by Little Pecan Bayou. Figure 1 below shows a vicinity map of the location of the project area.

Figure 1: Project Location Map

The project area consists of approximately 24,600 acres of fresh to brackish marsh. The federal sponsor is the Natural Resource Conservation Service (NRCS), and the local sponsor is the Louisiana Department of Natural Resources (LDNR).

The project area includes existing features that affect the hydrology of the project study area. These features include the elevated roadbed of Louisiana Highway 82, canals, levees, plugs, and existing water control structures in Little Pecan Bayou and the surrounding bayous. These features prevent or impede fresh water flow from north to south i.e. to the unmanaged marshes south of LA Hwy. 82. The project boundaries, as outlined in the scope of services, are shown in Figure 2.

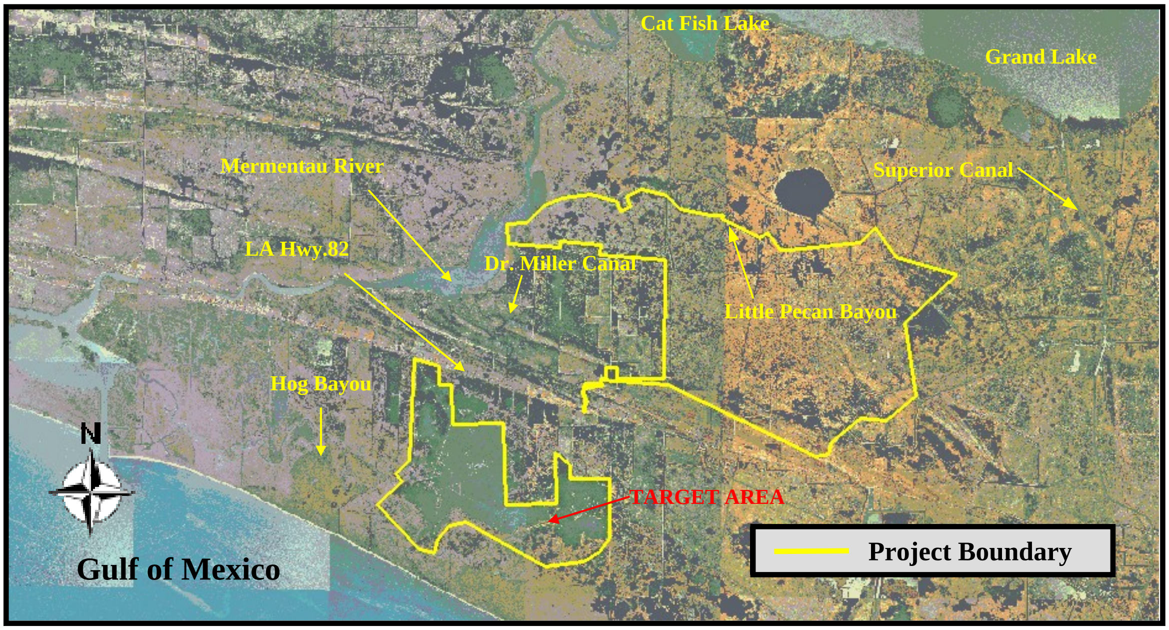


Figure 2: Base Map Showing Boundary Of The Project

1.2 PROJECT OBJECTIVE

In order to assess the impact of the proposed project features, which will be further described in Section 1.3, both LDNR and NRCS have proposed using a hydrodynamic and salinity numerical model to study the impact of the project features on the hydrology of the area. The model will be used to address two main goals set forth by the government agencies. These goals are to:

- Introduce fresh water to marsh areas south of Highway 82 especially in the brackish marshes to the south, thereby reducing salinities and lessen salinity spikes.
- Improve marsh productivity, reduce marsh loss, and increase submerged aquatic vegetation within the project limits.

Based on the numerical model results, both LDNR and NRCS will be able to assess whether or not the proposed project features will remain as planned, be modified, or be deleted from the project scope. It should noted that the performance of the this proposed project will be evaluated only for the time period where field data were collected and was used to calibrate and validate the model. Conclusions cannot be drawn regarding the performance of the project under all possible hydrologic and meteorologic conditions. In order to determine if the project would meet the objectives under all possible conditions, a long-term record of water levels in Grand Lake and in the Gulf of Mexico should be considered. The availability of differential water head between these two water bodies is the main controlling factor of delivering fresh water to the target area. The periods during which differential water head is available can be checked against the periods of high salinity in the target area, and as such, conclusions can be drawn of whether the project meets the objectives during these times. Such analysis, though, is beyond the scope of this project and was not requested.

Numerical modeling has been used extensively to offer practical engineering solutions to various engineering, environmental, and ecological studies. Numerical models are an efficient and inexpensive tool that offers solutions to complex hydrologic systems. The use of a numerical model for this project has allowed decisions to be made as to the most effective design, location, and operation scheme of the proposed project features. The model has provided a tool for the assessment of the effectiveness of each of the proposed project features.

The model was initially calibrated and validated for the existing hydrologic conditions. Afterwards, a direct comparison of the "Base Run (Existing Conditions)" and the "Conceptual Design Run (with proposed project features)" was performed. The model provided information regarding salinity and water level fluctuations, velocities, and discharges throughout the project area. The salinity transport was computed through an Advection Dispersion (AD) module, which was dynamically coupled with the hydrodynamic model. The final results of the model for water level, velocity, discharge, and salinity were displayed through time series graphical plots, animations, and contour map illustrations.

1.3 PROJECT DESCRIPTION

Upon field observations and visual inspection of the Digital Ortho Quarter Quad (DOQQ) maps for the project area, it was observed that the majority of water movement throughout the project limits occurs within a network of channels, trenasses, and canals, rather than through shallow sheet flow movement. The project study limits also include various small shallow lakes mixed with inundated marsh areas. These features serve mainly as areas of overflow from the various canals and channels, and act as storage areas during excessive rain events.

The conceptual project features as proposed in the scope of services included channel improvements and freshwater introduction structures that are expected to improve freshwater flow north to south across Highway 82. The conceptual design of the proposed project included two channel improvement locations:

1) Widening and deepening of the existing canal (Freshwater Introduction Canal) connecting Little Pecan Bayou and Miller Canal. The alignment runs through existing structure numbers 16,17,18,13,19,20, and 21 (Figures 3 through 8).

2) Widening and deepening Miller Canal to open water south of LA Hwy. 82 (Figures 3, 8 and 9)

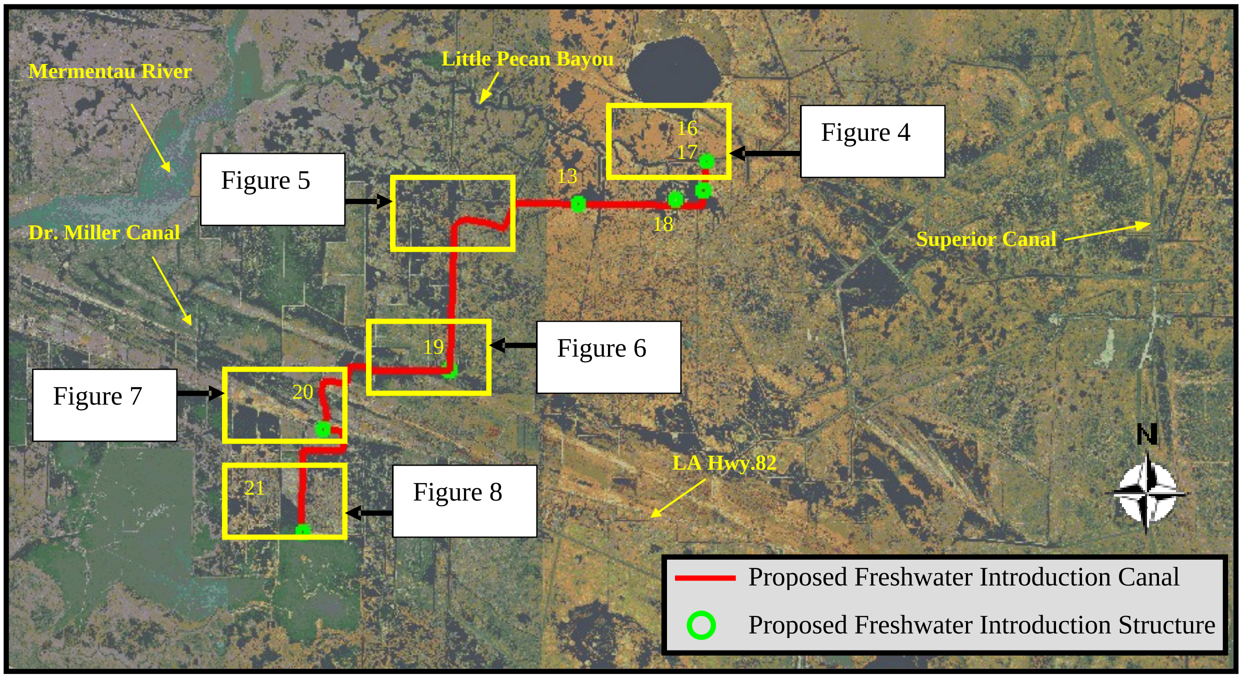


Figure 3: Base Map Showing Project Proposed Features

The conceptual design of the proposed project also includes various proposed freshwater introduction structures shown in Figures 3 through 9. The freshwater introduction structures include:

- A gated water control structure at the junction of the freshwater introduction canal linking Miller Canal and Little Pecan Bayou (Structure 16, Figure 4).

- Gated control structures at various locations along the freshwater introduction canal south bank of Little Pecan Bayou. (Structures, A, B, C, D, E, 19, 20, and 21, Figures 5,6,7 and 9).

- A gated control structure in the freshwater introduction canal north of Highway 82. (Structure 20, Figure 8)

The project features also include creation of Earthen Terraces. These are approximately 150 –200’ long vegetated terraces to be placed within the shallow open water area south of LA Hwy. 82. (Figure 10)

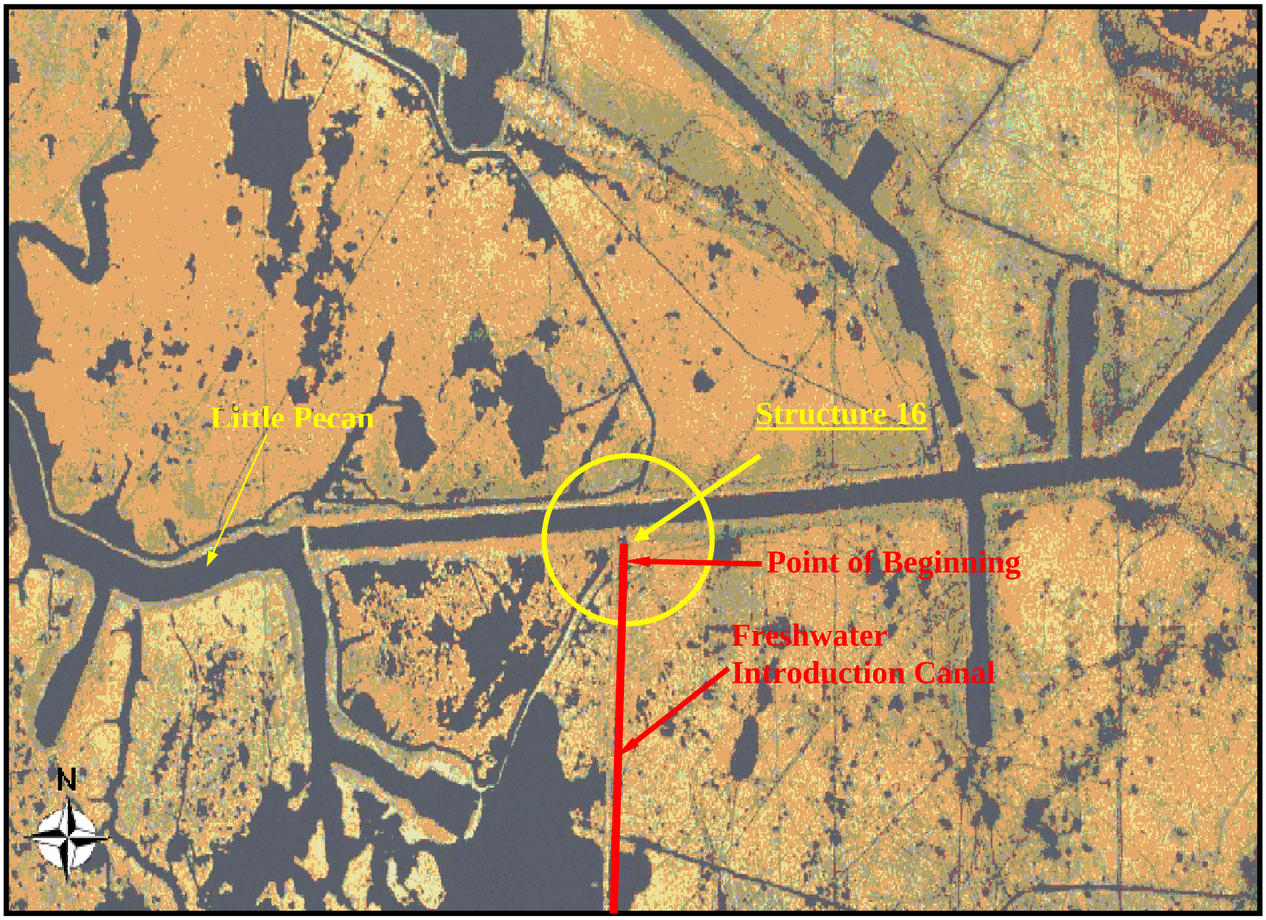


Figure 4: Proposed Project Structure at the Intersection of Freshwater Introduction Canal with Little Pecan Bayou (Structure 16).

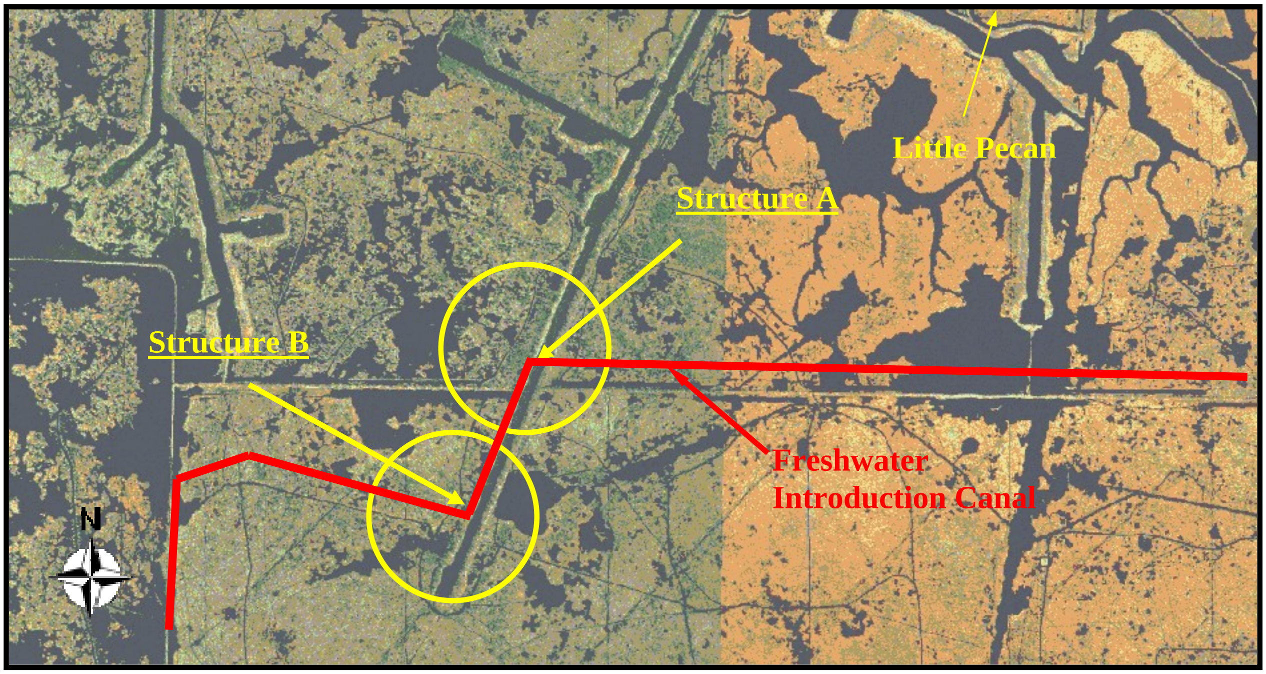


Figure 5: Proposed Improvements For Freshwater Introduction Canal (Structure A, B)

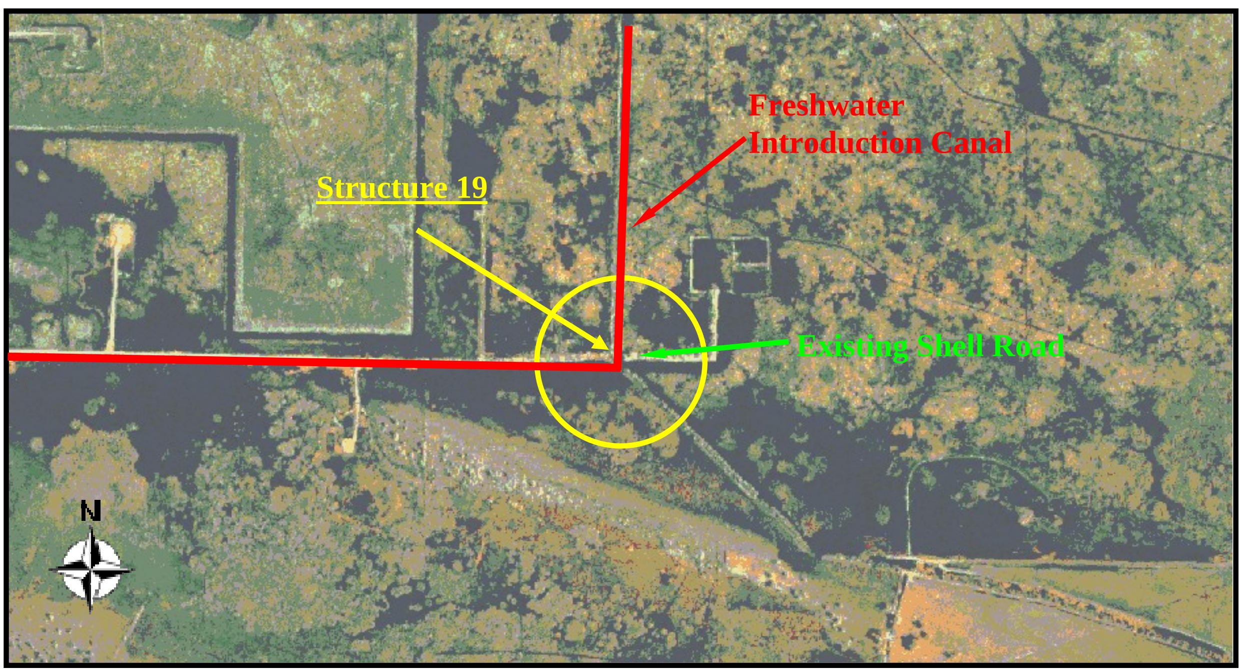


Figure 6: Proposed Project Structure At The Intersection Of Freshwater Introduction Canal With Existing Shell Road (Structure 19)

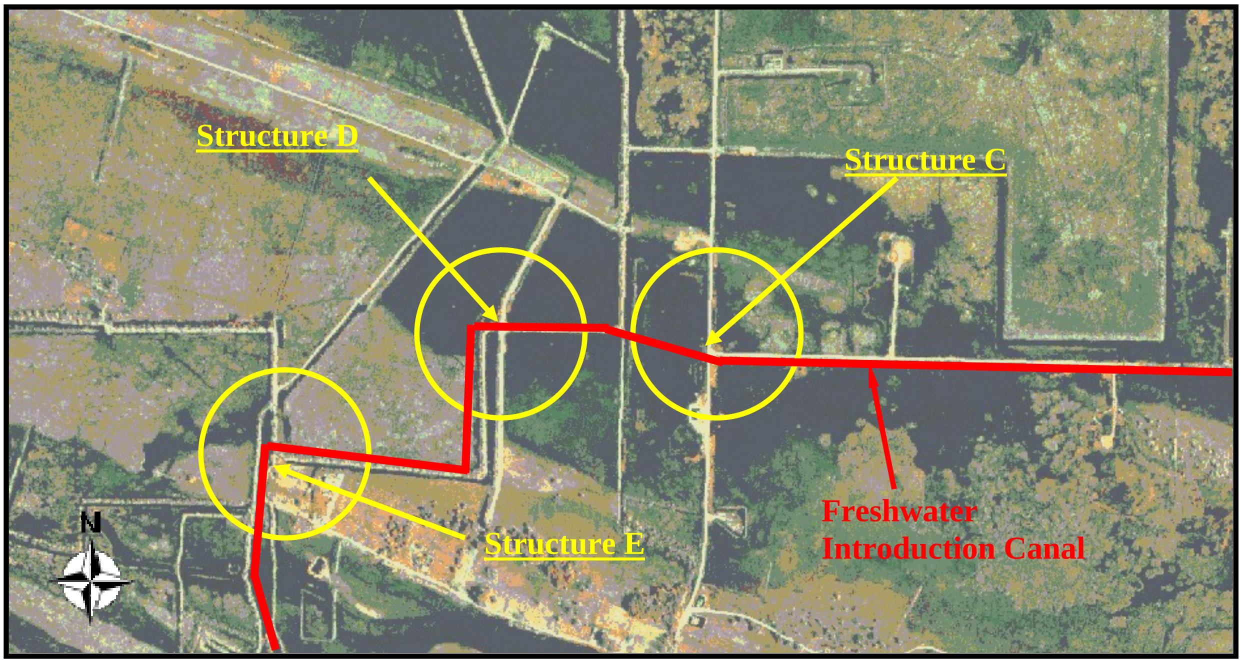


Figure 7: Proposed Project Structure At The Intersection Of Freshwater Introduction Canal With Existing Shell Roads (Structure C, D, E)

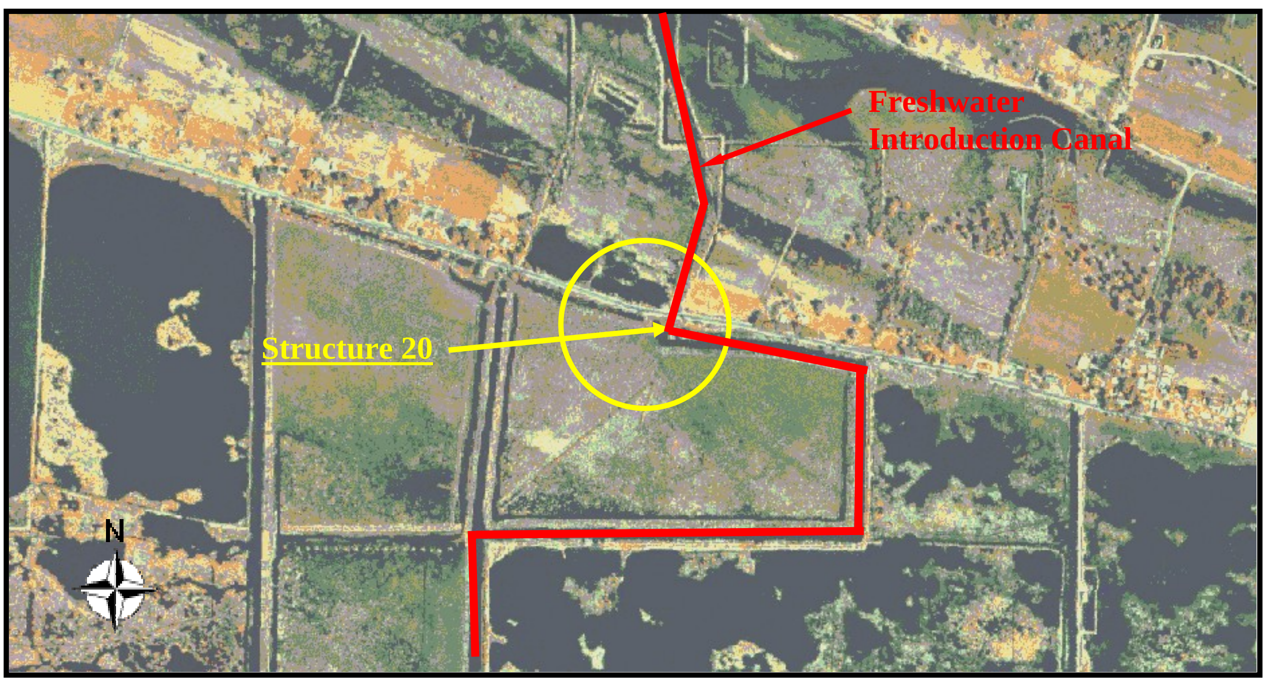


Figure 8: Proposed Project Structure At The Intersection Of Freshwater Introduction Canal With LA Hwy. 82 (Structure 20).

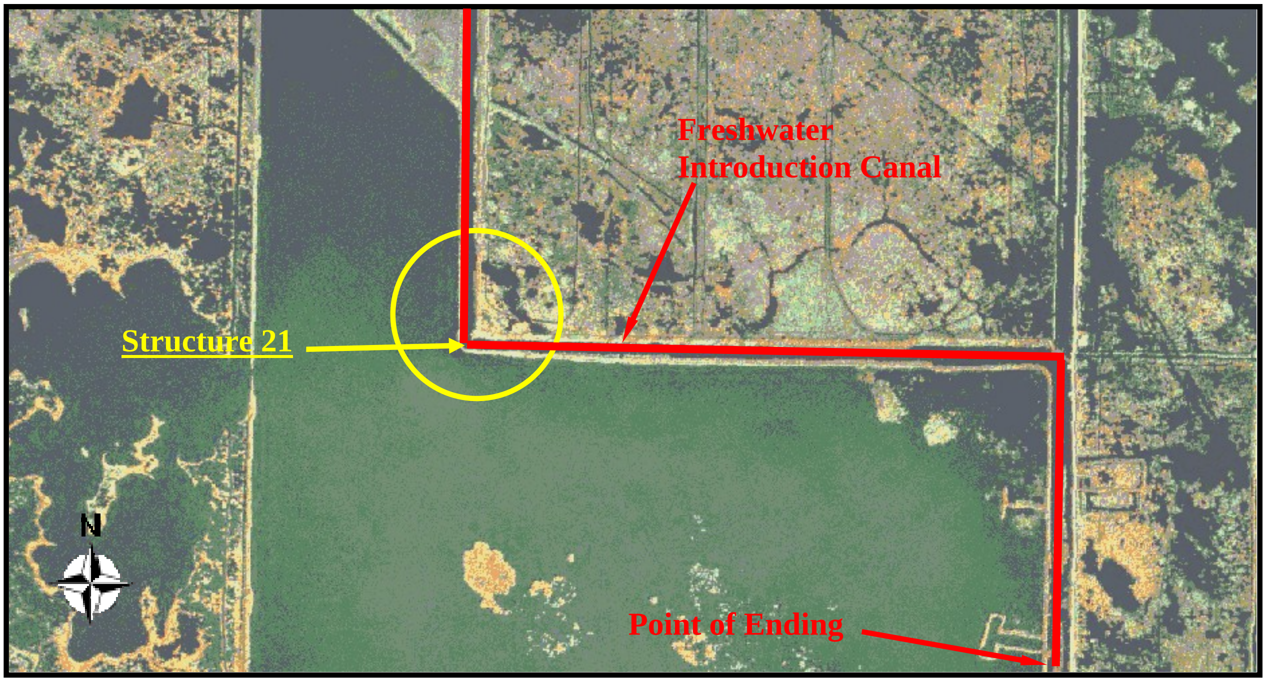


Figure 9: Proposed Project Structure At The Intersection Of Freshwater Introduction Canal With Existing Levee (Structure 21)

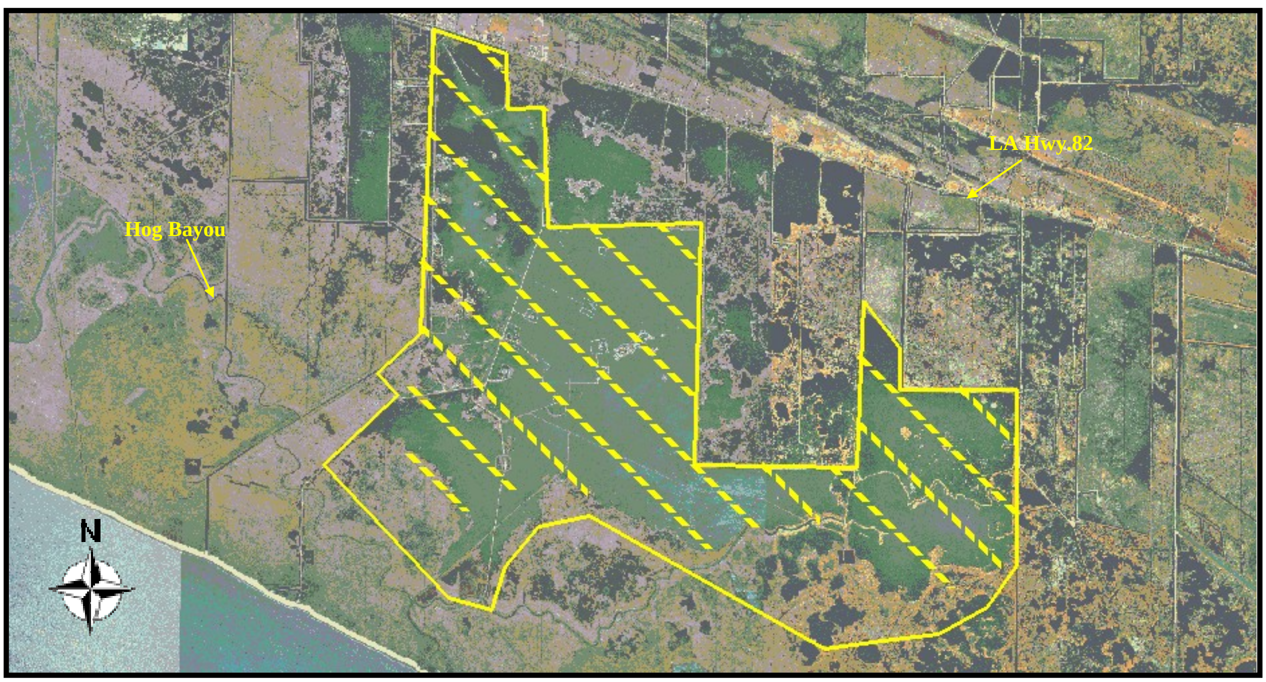


Figure 10: Conceptual Vegetated Earthen Terraces For Shallow Open Water Area South Of Highway 82

In summary, the simulation of the conceptual model design as agreed upon by the government agencies (via email sent from Mr. Clark Allen dated 01/14/04) includes the following:

1) Freshwater introduction canal with a 10’ bottom width, 4’ deep, and 3:1 side slopes. The canal will follow the existing slope from structure 16 to Highway 82.
2) Include existing structures 13 and 18 into the model.
3) Model existing structure 15 as an existing plug.
4) Model proposed structure 20 with flap gates.
5) Structures 19 and 21, and all culverts under existing shell roads, shall be sized to satisfy the local drainage requirements.

A detailed discussion of the model setup, calibration, and validation results is presented in Chapter Two, while implementation of the proposed project features is described in Chapter Three.

II. CHAPTER TWO

2.1 MODEL SELECTION

The first step in performing a numerical model study is to select an appropriate model capable of capturing the hydrologic characteristics of the project area. It is well beyond the scope and budget of this project to perform an elaborate model selection task. Therefore, an adequate modeling tool will be selected for this study based on the background information available about the project site.

The focus of this project is to introduce fresher water into the marsh south of LA Hwy. 82 through various canals within the project area, and to reduce the amount of saltwater intrusion from the Gulf of Mexico. It is important here to mention that the area of this project is hydrologically connected to another CWPPRA project area, namely the South Grand Chenier Hydrologic Restoration Project (ME-20). With this in mind, setting up separate models for each project will not accurately mimic the hydrology of the area. After consulting with federal and local government agencies for the two projects, it was decided to set up one numerically coupled model for the two projects. The methodology followed to set up the model is described in Section 2.3.

Field observations and inspections of the project area, indicate that the water movement within the Little Pecan Bayou Control Structure Project boundaries predominantly occurs within the banks of a network of channels, trenasses, and canals, rather than through shallow sheet flow movement. Meanwhile, the water movement within the South Grand Chenier Hydrologic Restoration Project occurs as a combination of shallow sheet flow movement and open channel flow. Therefore, an appropriate modeling tool for this study should be to dynamically integrate these two flow regimes. A one and two-dimensional coupled modeling approach will be used for modeling the flow through the channel network, the flow through marsh areas, and the exchange between the channels and the marsh. It should be noted that a three-dimensional model would not be needed since the project area is predominately shallow (water depth in the project area range between 2 and 15 feet) making salinity stratification negligible.

There are several reliable coupled modeling systems commercially available on the market. Differences between these packages are primarily in their ability to adequately model hydraulic structures, and in their pre-and post-processing capabilities. One of the popular and widely used coupled modeling packages is MIKE FLOOD. This software is produced by the Danish Hydraulic Institute (DHI).

MIKE FLOOD integrates the widely used one-dimensional model MIKE 11 and the two-dimensional model MIKE 21 into a single package. The special features of MIKE FLOOD include:

- Conserves mass and Momentum through links between MIKE11 and MIKE21;
- Simulates over bank flow from channels to floodplains through lateral links;
- Simulates the hydraulics and operation plans of water control structures;
- Interacts with GIS packages;
- Provides a user-friendly graphical interface for data preparation, processing, and analysis;
- Provides an on-line help system, user manual, and technical reference documentation;

MIKE FLOOD can also be used to model applications such as:

- Floodplain analysis and management;
- Storm surge studies;
- Urban drainage projects;
- Dam break studies;
- Hydraulic design of structures;
- Large-scale estuarine analysis.

Using MIKE FLOOD allows the modeler to take advantage of the available capabilities of both MIKE11 and MIKE21. A list summarizing these capabilities is included below:

MIKE11:

- Comprehensive hydraulic structures routines;
- Branching and looping channel networks;
- Rainfall-runoff transformation options;
- Sediment and water quality constituents routines;

MIKE21:

- Overland shallow lakes and ponds dynamic equations routines;
- Wetting and drying capabilities;
- Sediment and water quality constituents.

2.1.1 MODEL RESOLUTION

The alignments of the channels were digitized directly from geo-referenced aerial imagery (1988 DOQQ) in order to capture the alignment of each channel. Typical spacing between the digitized computational points for this project was in the range of 200 to 600 feet.

For the marsh areas where a two-dimensional model will be used, the model grid resolution is an important factor. It affects the model's ability to resolve the spatial variability of the flow characteristics. Typically, a grid refinement exercise needs to be performed in order to determine the optimum grid size for each application. Sometimes in practical applications, the grid has to be finer than the optimum grid size in order to capture particular features of importance. In the project discussed here, a grid resolution of 75 meters (approximately 250 ft) in both directions of the horizontal plane has been selected. This grid size was selected to capture the exchange between over-bank and channel flows. This grid size is finer than the size needed to resolve the circulation pattern in and near the project area. In the horizontal plane, the grid has 83 x 303 computational nodes (25,149 computational points).

2.2 DATA COLLECTION & REVIEW

2.2.1 BATHYMETRIC DATA

The accuracy of the results of any numerical model is proportional to the accuracy of the bathymetric data. For one-dimensional numerical models, the bathymetric information is required in the form of cross sections along the length of channels within the model domain. Spot elevations to define the storage capacity of all open water bodies are also required. The following guidelines are used as a general standard practice to identify the locations where surveyed cross sections are needed:

- Upstream and downstream of abrupt changes in channel geometry;
- At all canal intersections (cross section at each approaching leg);
- At all channel bed slope changes along the channel's longitudinal direction;

- Upstream and downstream of all existing structure locations.

For two and three-dimensional numerical models, bathymetric information is required in the form of bare earth spot elevations within all open water areas, canals, and marshes within the project model domain. The information used to generate the two-dimensional bathymetry file include:

- Spot elevations of the bottom of open water bodies, canals, and open marshes;

- Spot elevations of all significant hydrologic barriers or features (i.e. levees, ridges, etc.).

Upon visual inspection of this project's area and through the use of aerial photography, it was estimated that 103 cross sections and 165 spot elevation points would need to be surveyed in order to create the bathymetry for the numerical model. The channel inverts in the project area ranged from +0.0 to approximately –10.0 feet NAVD88 (National Adjusted Vertical Datum of 1988).

On July 24, 2002, survey crews from C.H. Fenstermaker & Associates were mobilized to the project site to survey the required cross sections and spot elevations needed to set up the numerical model. The surveying effort included establishing horizontal and vertical positions on three new secondary monuments within the South Louisiana Coastal Wetlands (SLCW) Secondary Global Positioning System (GPS) Network. These monuments were to be used in conjunction with existing secondary monuments to perform the necessary survey effort. The approximate location of the proposed monuments, cross sections, and also data sondes were determined jointly by C.H. Fenstermaker and Associates, Inc. and LDNR personnel. The secondary monument locations were strategically selected in order to populate the existing LDNR secondary network in the areas that were lacking sufficient monumentation to collect the necessary survey data and to comply with specifications produced by LDNR entitled, "A Contractor's Guide to Minimum Standards". Once installed, the new monumentation, along with the existing monuments, allowed the entire project to be surveyed utilizing GPS Real-Time Kinematic (RTK) techniques. The survey crews were able to successfully complete the proposed survey in the allocated time initially proposed in the work plan for the project. Figures 11 through 16 below show the final location of the project's cross-sections and surveyed points.

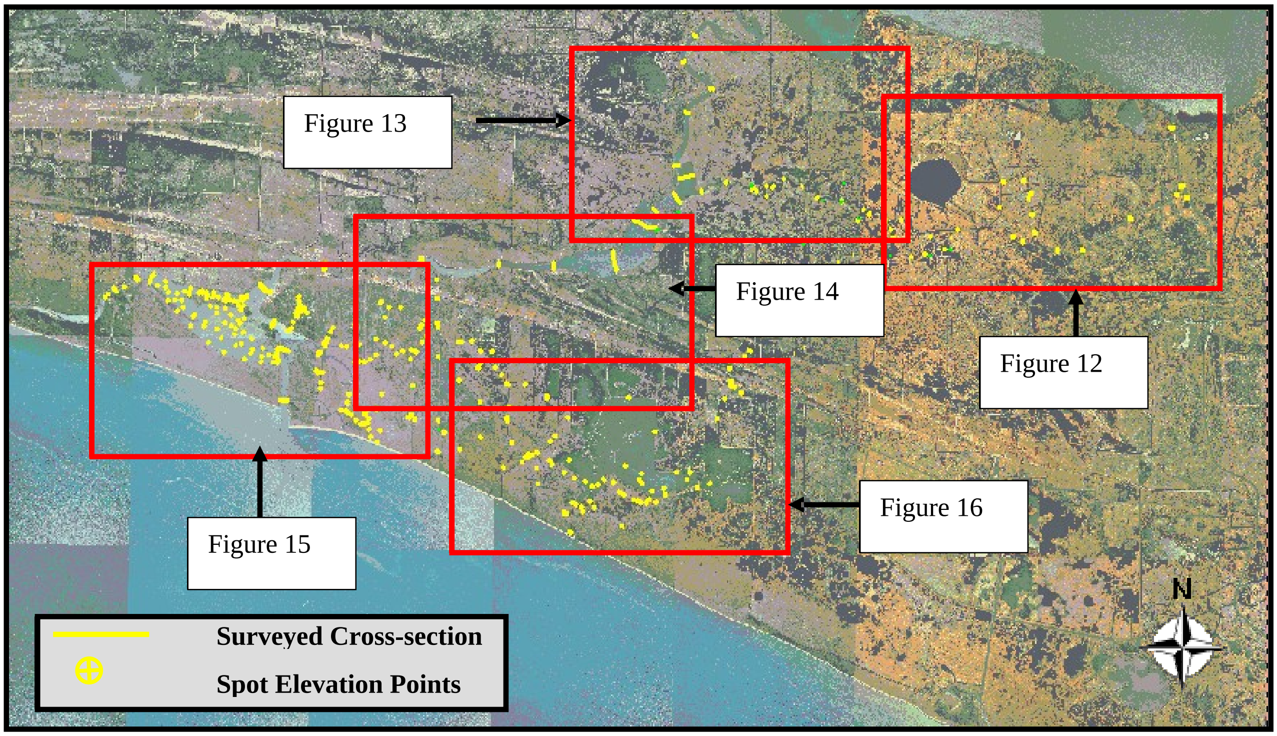


Figure 11: Basemap Showing Location Of Final Surveyed Cross-Sections (103 Total)

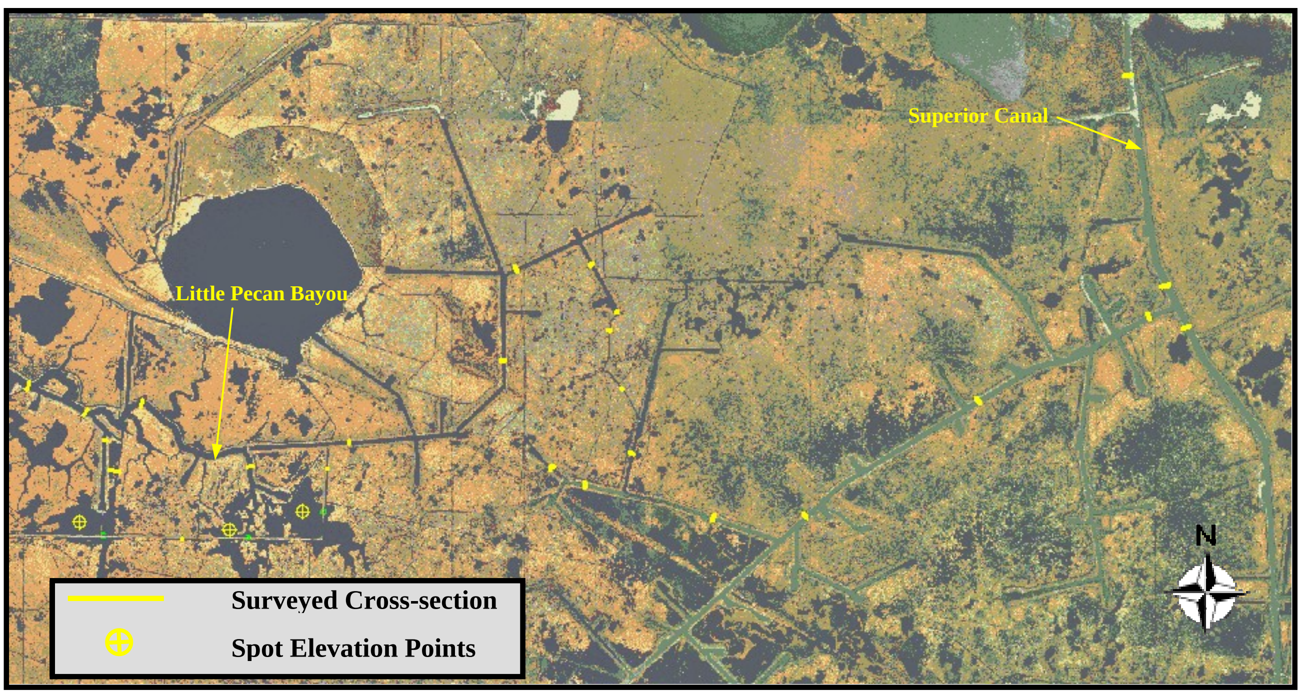


Figure 12: Map Showing Location Of Final Surveyed Points & Cross-Sections.

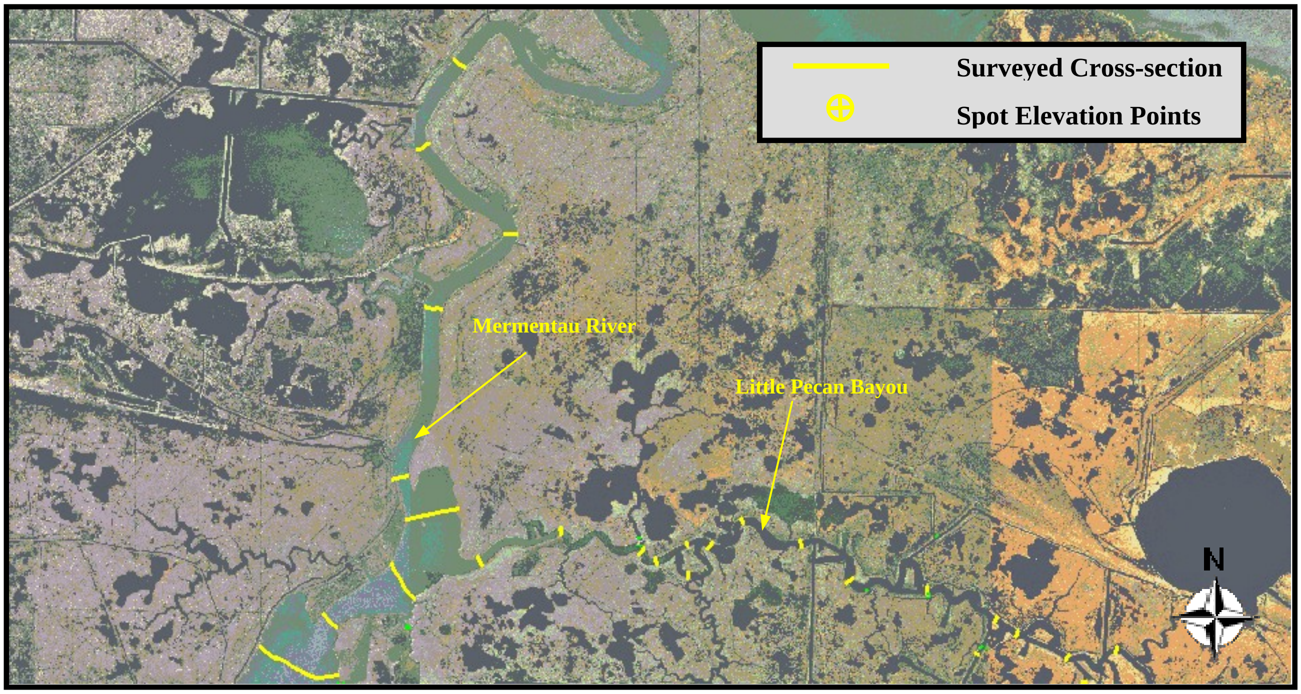


Figure 13: Map Showing Location Of Final Surveyed Points & Cross Sections.

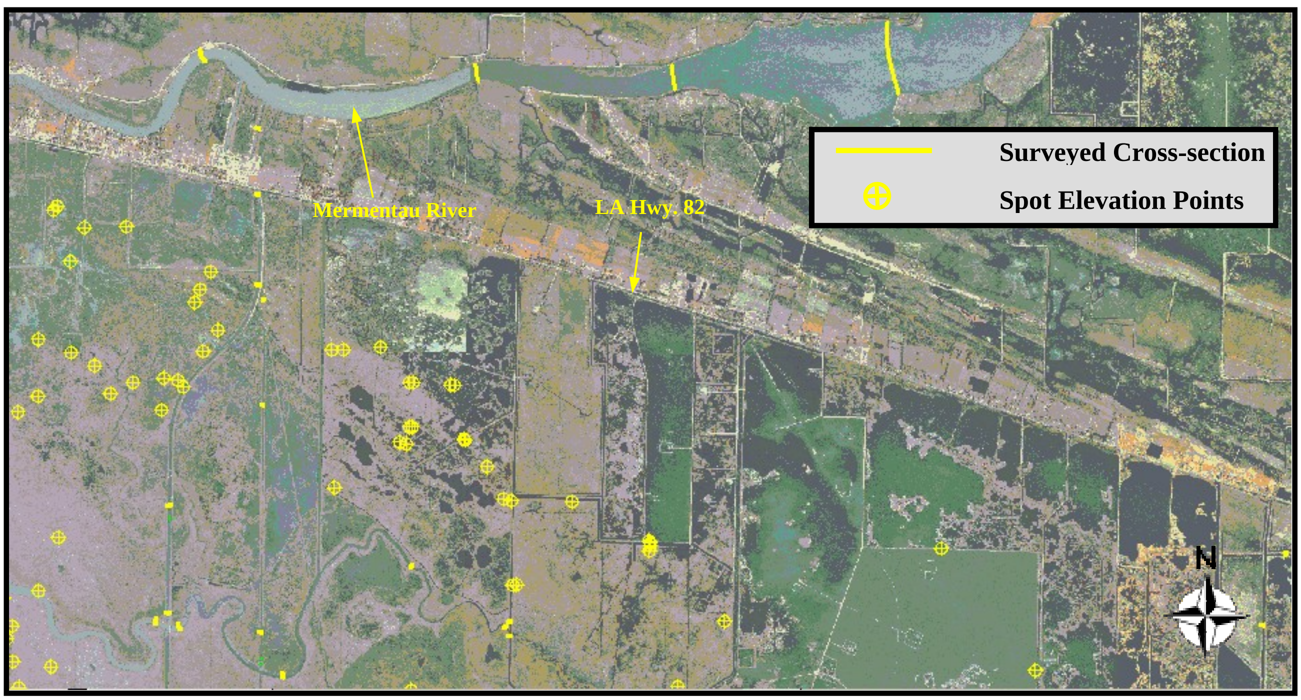


Figure 14: Map Showing Location Of Final Surveyed Points & Cross Sections.

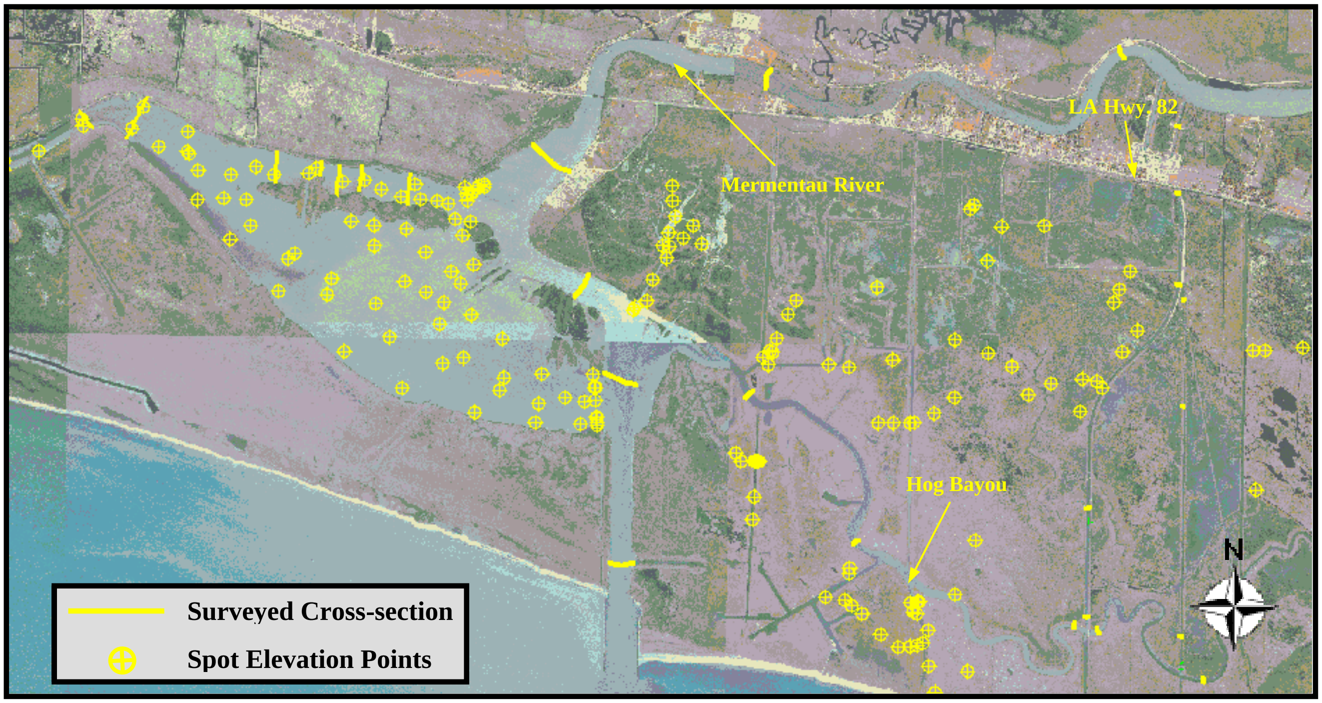


Figure 15: Map Showing Location Of Final Surveyed Points & Cross Sections.

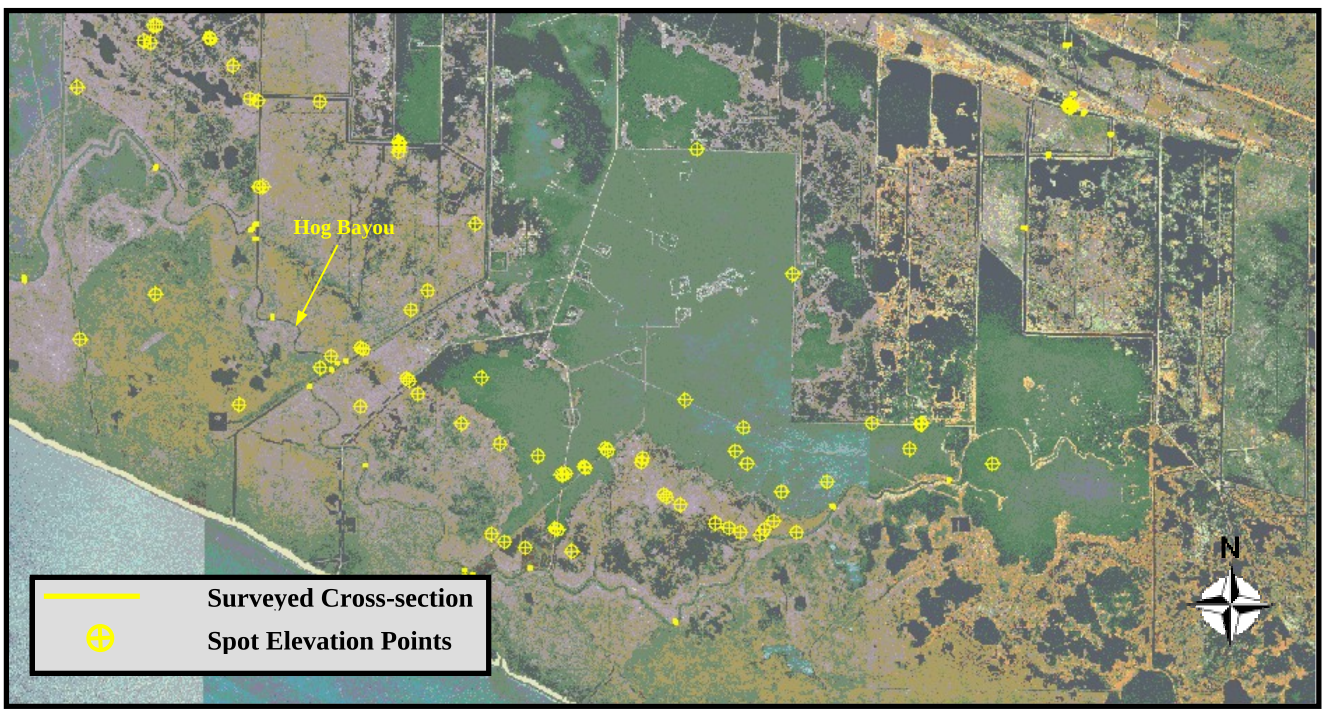


Figure 16: Map Showing Location Of Final Surveyed Points & Cross Sections.

Detailed information and dimensions of existing hydraulic structures were also surveyed. Survey crews were instructed to collect all possible information needed to accurately set up the model's structure components. To facilitate the survey effort for hydraulic structures, the field crews utilized coding techniques that are common in the surveying industry. Figures 17 through 21 describe the basic coding requirements for structures like or similar to the ones shown in these illustrations. Figure 22 illustrates a sample page of field notes that were taken at the LA Hwy. 82 structure, along with a color photograph for the records.

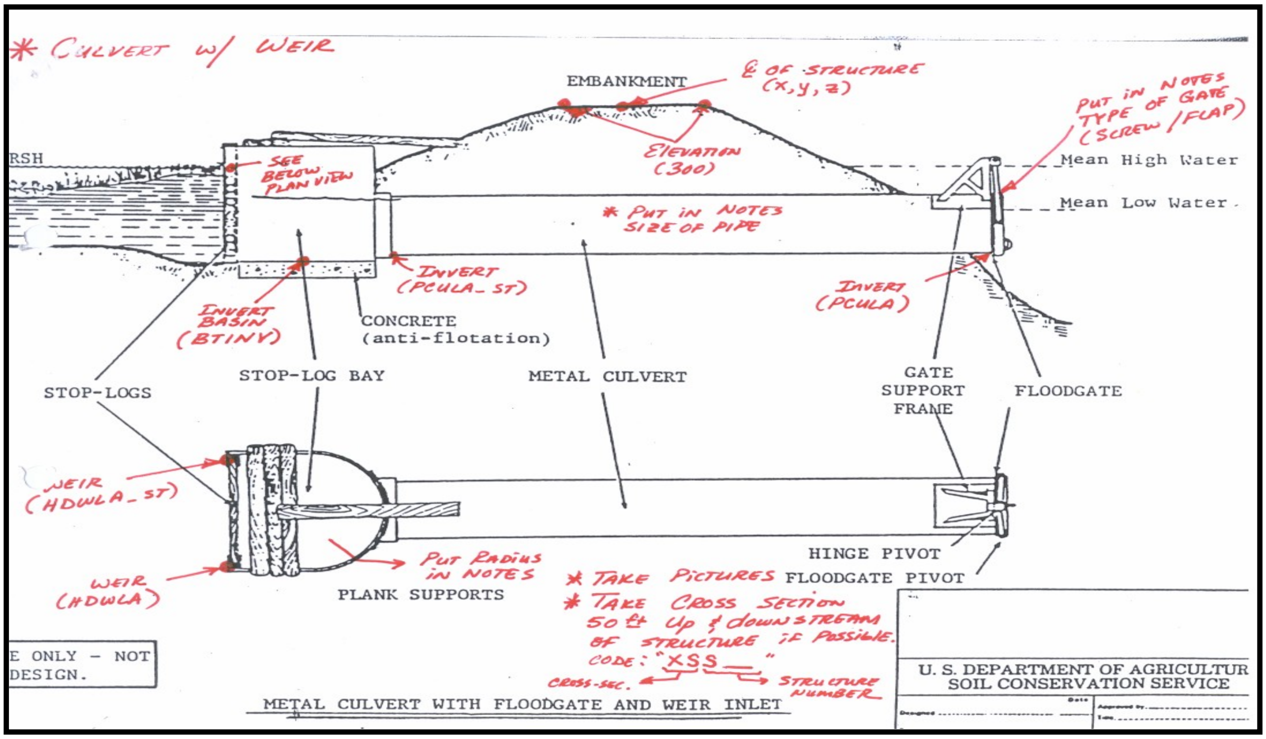


Figure 17: Basic Survey Coding For Culvert System With Flapgates And Stop Logs.

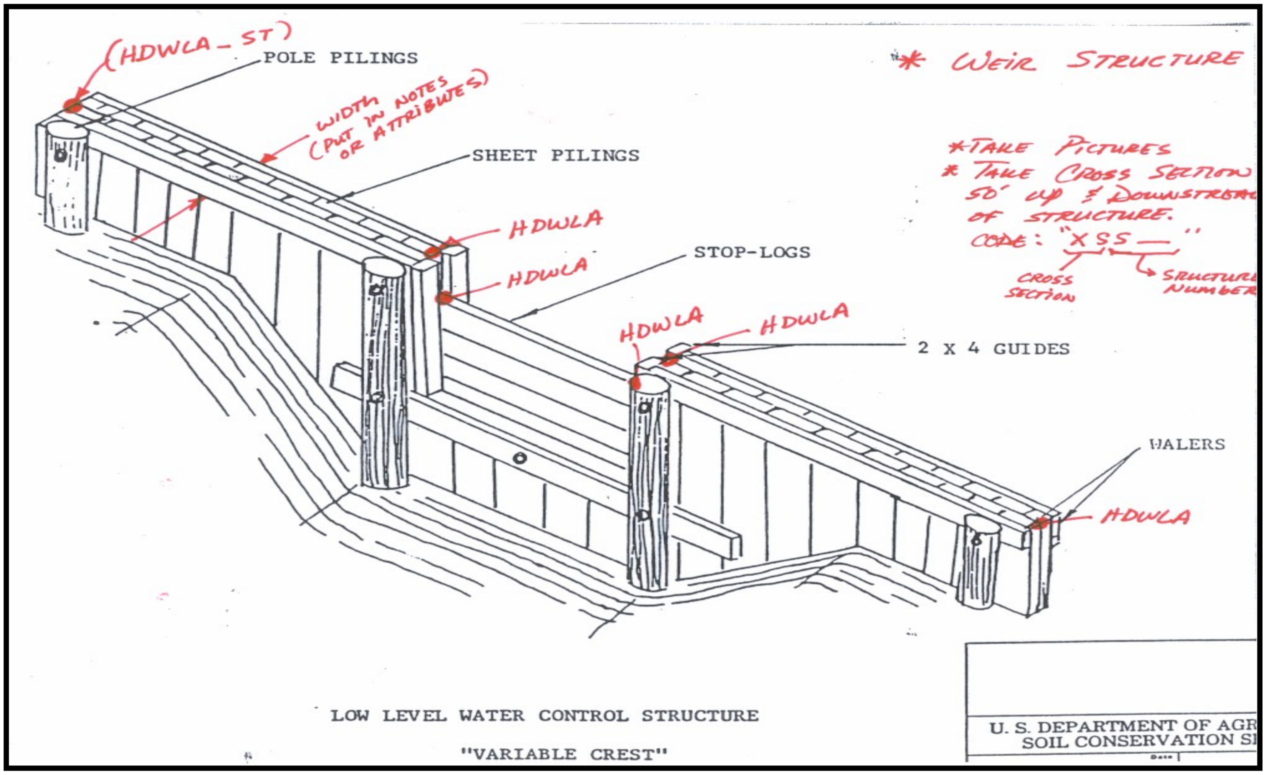


Figure 18: Basic Survey Coding For Weir Structure

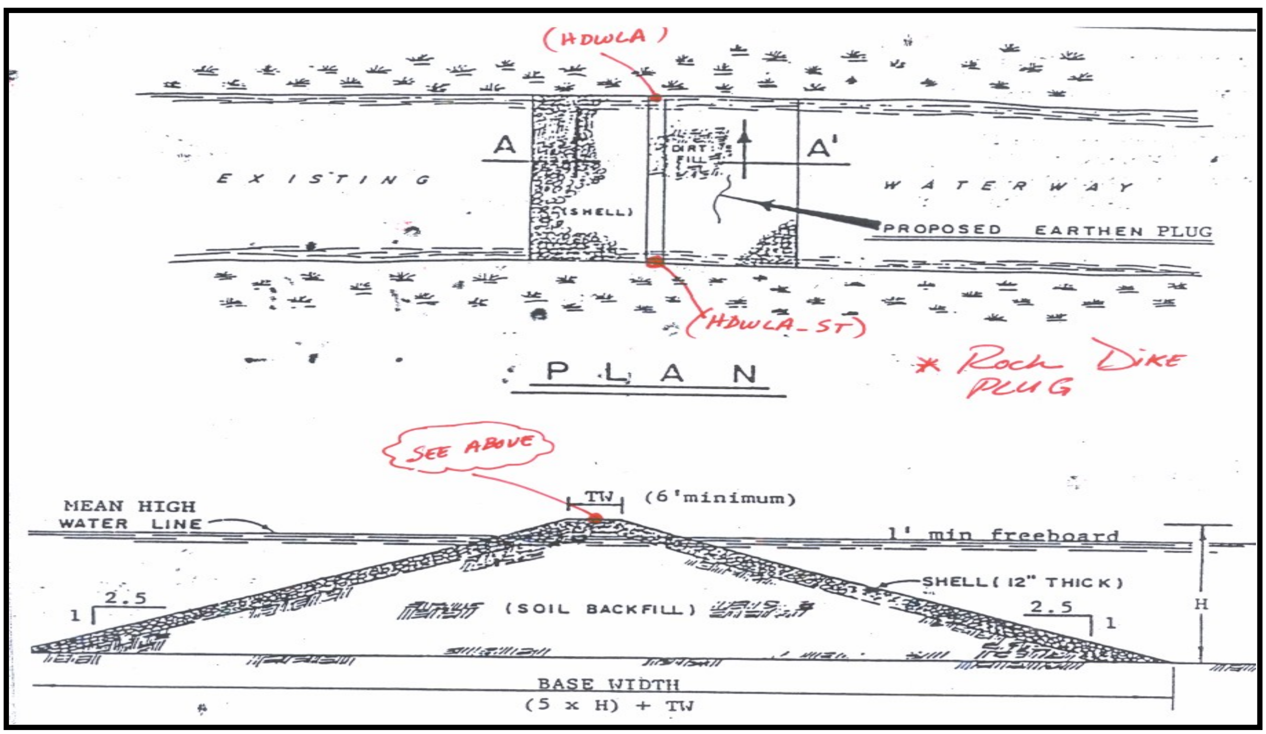


Figure 19: Basic Survey Coding For Earthen Or Rock Plug

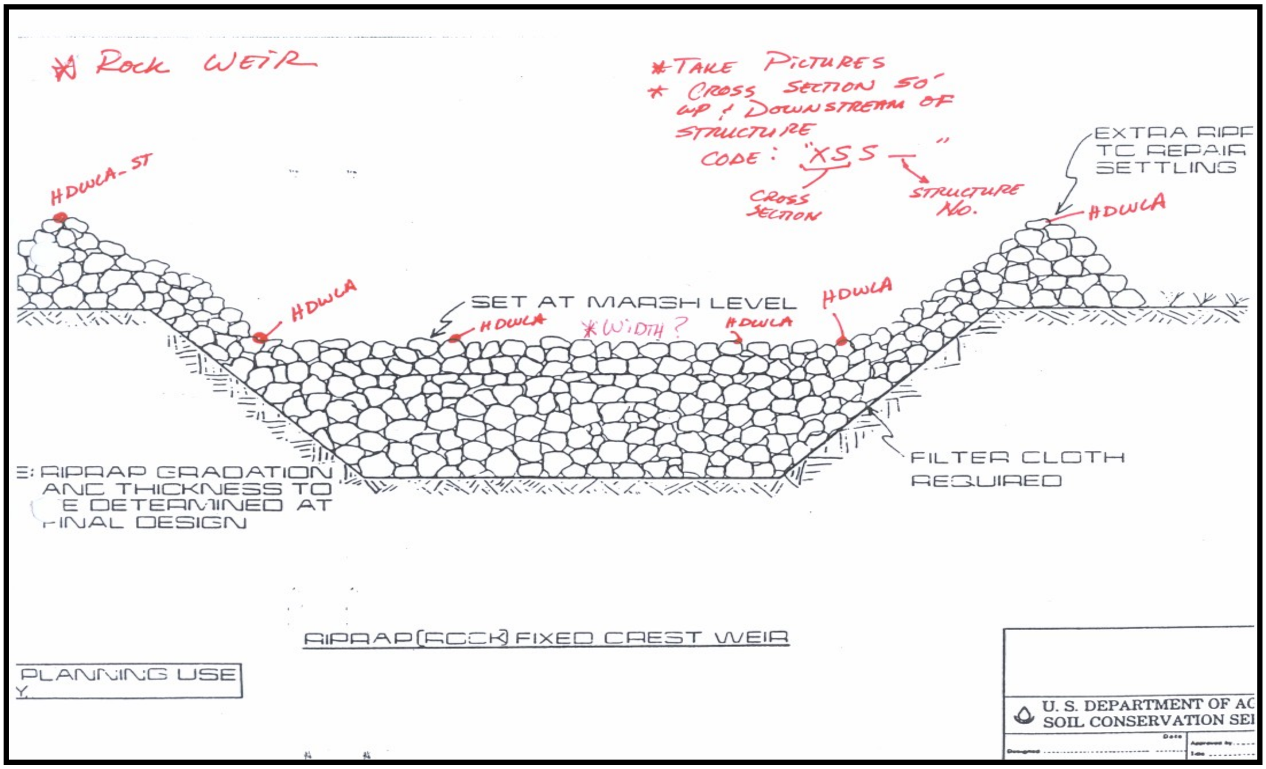


Figure 20: Basic Survey Coding For Rock Weir Structure

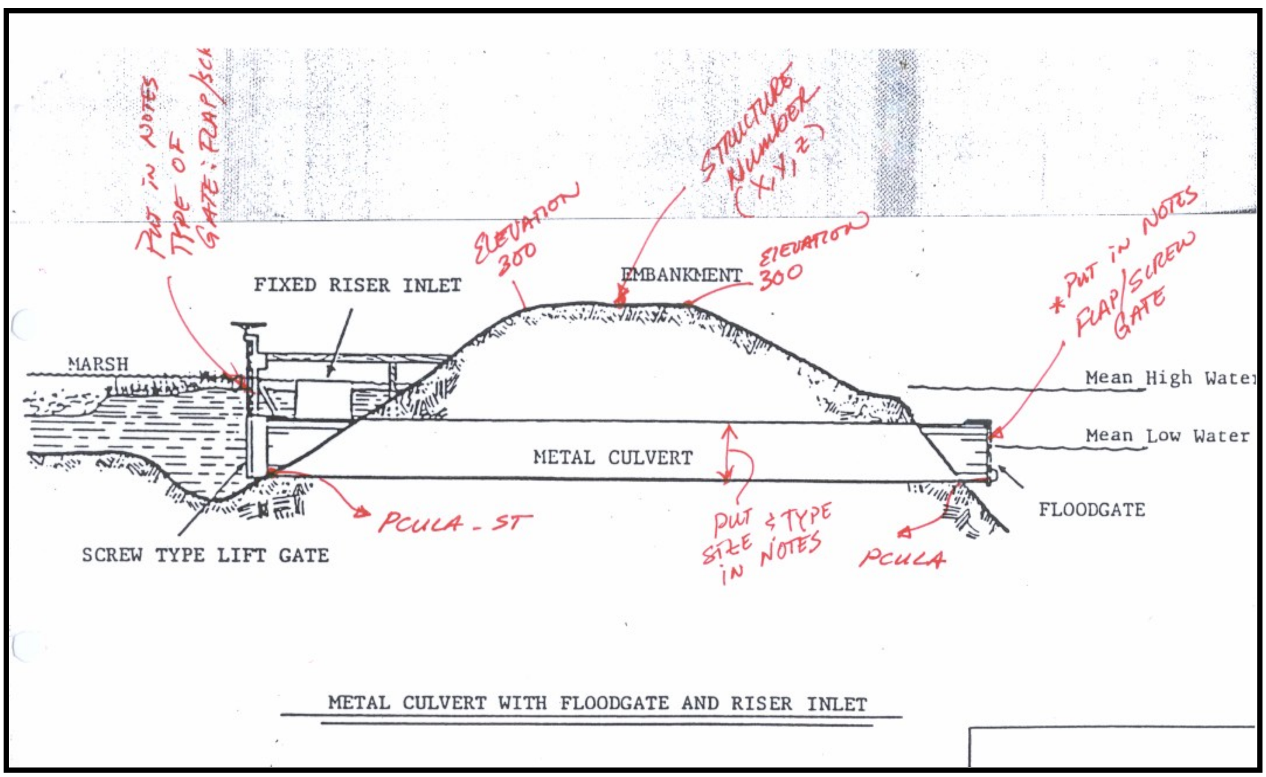


Figure 21: Basic Survey Coding For Culvert With Screw Gate And Flapgate Inlets.

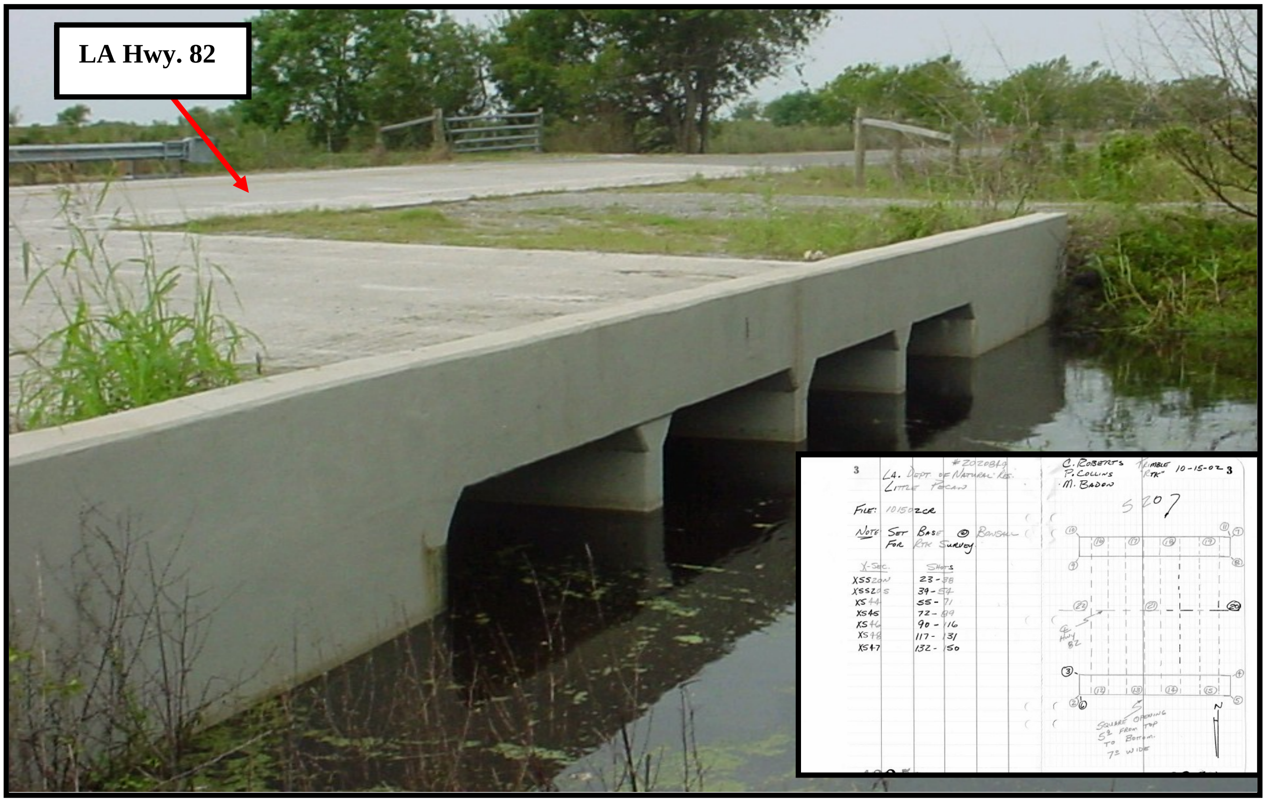


Figure 22: Example Clip From Survey Field Book Describing LA Hwy. 82 Existing Box Culverts.

2.2.2 HYDROLOGIC DATA COLLECTION

Hydrologic data is needed to set up the boundary conditions and to calibrate and validate the numerical model. The hydrologic parameters needed for this modeling effort are water level, velocities, discharge, and salinity. Per LDNR's recommendations through previous experiences, YSI 600-OMS data sondes (manufactured by YSI, Inc) were used in this study. It is a product similar to the YSI 6920 data sonde currently used by LDNR. This device measures water level, water temperature, and specific conductivity.

Information from continuous recorders G1, G6, G7, G8 and G9 were used as boundary conditions for the numerical model, while G2, G3, G4, and G5 were used for the model's calibration and validation. Locations of all the gages are shown in Figure 23.

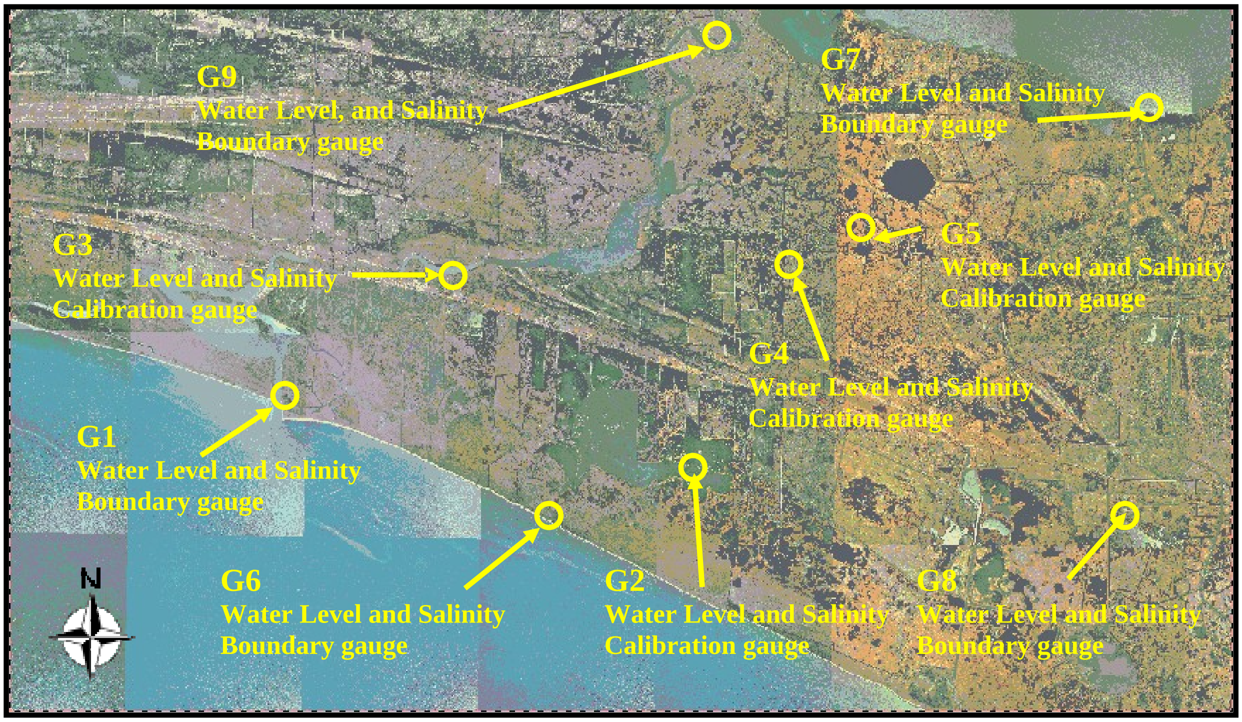


Figure 23: Basemap Showing The Location Of Continuous Recorders Used For The Model.

Not shown in Figure 23 is the continuous recorder used to collect wind direction and speed. This recorder is located in Lake Charles, Louisiana and is owned and operated by Louisiana State University-Southern Regional Climate Center. Figures 24 and 25 show some pictures of the monitoring stations mentioned above, while Table 1 shows the available data record at each station.

Figure 24:Water Level And Salinity Data Sonde
Installed In The Mouth Of The Mermentau River

Figure 25: Discharge And Water Level Gauge Installed
In The Mermentau River Near Grand Lake.

Recorder Name and Location	Data Type	Date From:	Date To:
G1, Mouth of the Mermentau River at the Gulf of Mexico	Water Level and Salinity	7/29/02	4/7/03
G2, Second Lake	Water Level and Salinity	8/1/02	4/30/03
G3, Mermentau River near BP canal	Water Level and Salinity	7/29/02	4/30/03
G4, Miller Property	Water Level and Salinity	8/20/02	4/30/03
G5 Little Pecan Bayou	Water Level and Salinity	7/29/02	4/30/03
G6, Beach Prong	Water Level and Salinity	8/1/02	4/30/03
G7, North Superior Canal at Grand Lake	Water Level and Salinity	8/22/02	4/30/03
G8, Superior Bridge	Water Level and Salinity	8/1/02	4/30/03
G9, Mermentau River at Grand Lake	Water Level and Discharge	8/22/02	6/3/03

Table 1: Record of Data Available at Each of the Monitoring Stations

2.3 MODEL SETUP

The steps needed to set up the numerical model for this project include:

1. Determining the extent of the numerical model domain. Care should be taken to ensure that:

    - The boundaries of the model extend beyond the area of interest.
    - The hydrologic or topographic adjustments and changes within the project area do not impact the conditions at the numerical model boundaries.

2. Setting up the channel network and the computational grid within the numerical model domain. (NOTE: In coastal Louisiana where a network of channels runs

through the marsh, it is not practical to include all the channels as some are quite small in dimensions and do not carry or convey significant flow).

3. Assigning surveyed and estimated cross sections to all channels included in the model domain.

4. Include storage areas into the one-dimensional model if they exist.

5. Include all hydraulic structures within the numerical model domain.

6. Assign proper boundary conditions to each open end of every channel in the numerical model domain.

The surveyed spot elevations shown in Figure 11 through 16 were combined with the surveyed cross-sections to generate the bathymetry input file for the numerical model. As discussed in Section 2.1, the grid resolution for the two-dimensional model area is 75 meters (approximately 250 feet) in both directions (north-south and east-west) in the horizontal plane. This grid is adequate to capture the circulation patterns of water level and salinity within the model domain. It should be noted that the vertical datum for all the bathymetric data as well as the water level data was set to NAVD 88, while the state plane Louisiana South Zone, NAD83 (National Adjusted Datum of 1983) was used as the horizontal datum.

2.3.1 SETUP OF CHANNEL NETWORK

The general layout of the channel network, boundaries, and hydraulic structures for the existing conditions are shown in Figures 26 and 27. An aerial is shown in the background of these figures to facilitate identifying the channels and their locations in the field.

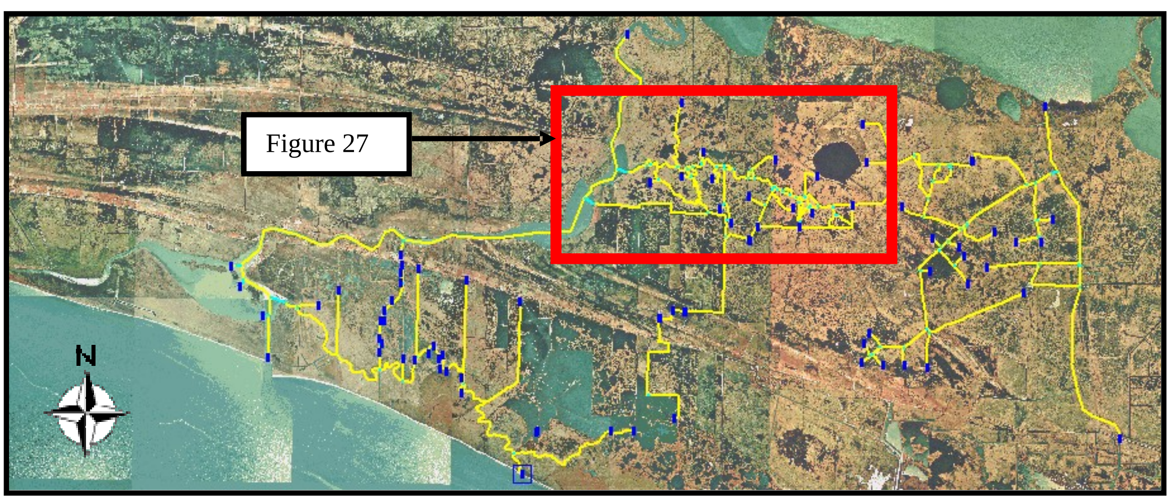


Figure 26: Basemap Showing The MIKE11 Channel Network, Cross Sections, Structures And Boundaries.

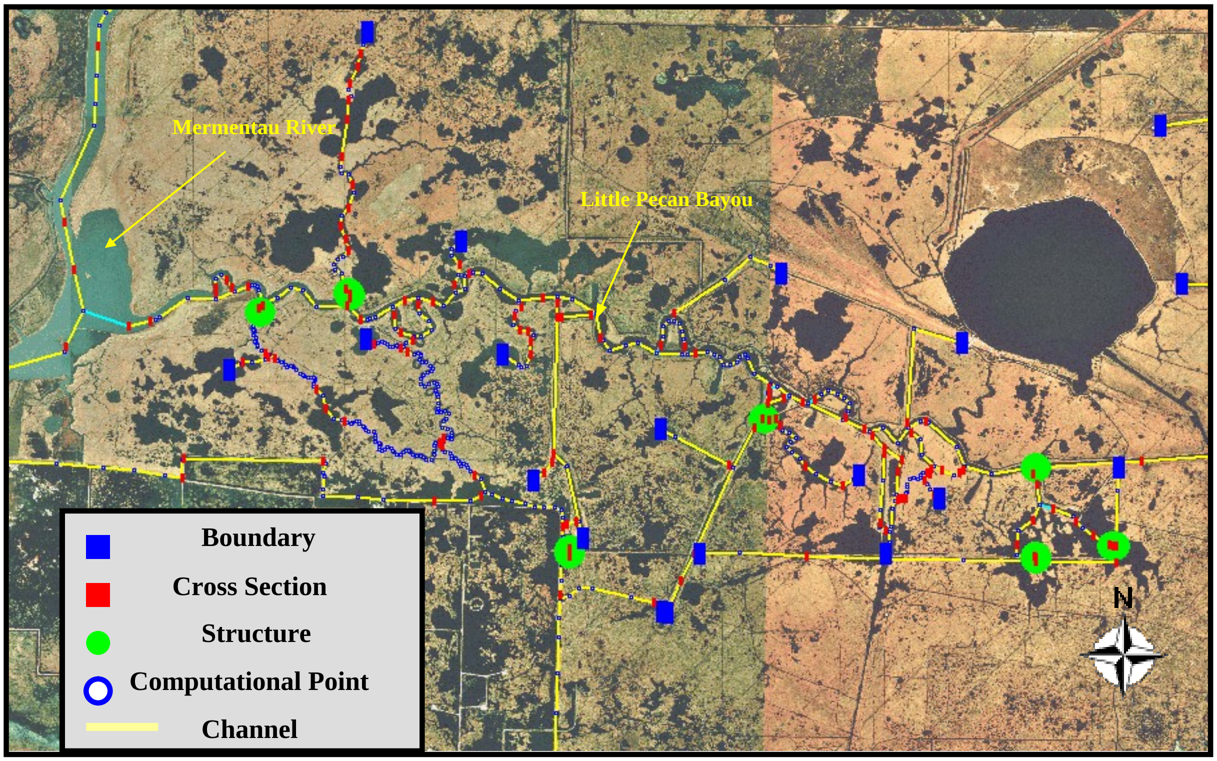


Figure 27: MIKE11 Channel Network, Cross-Sections, Structures And Boundaries.

An extensive effort was made to ensure that the channel connectivity mimics the field conditions. Although most of the flow is conveyed through the channel network and not through over-bank sheet flow, care was taken to include the storage areas of the open water bodies. Storage areas can, at times, have significant impact on attenuating the tidal signal and the transport of salinity.

2.3.2 SETUP OF TWO-DIMENSIONAL GRID

The bathymetric data for the project area, including any hydrologic barriers within the model domain, is shown in Figure 28 and 29. Figure 30 shows a three-dimensional visualization of Lower Mud Lake near the mouth of the Mermentau River. These figures show the level of topographic details included in the model.

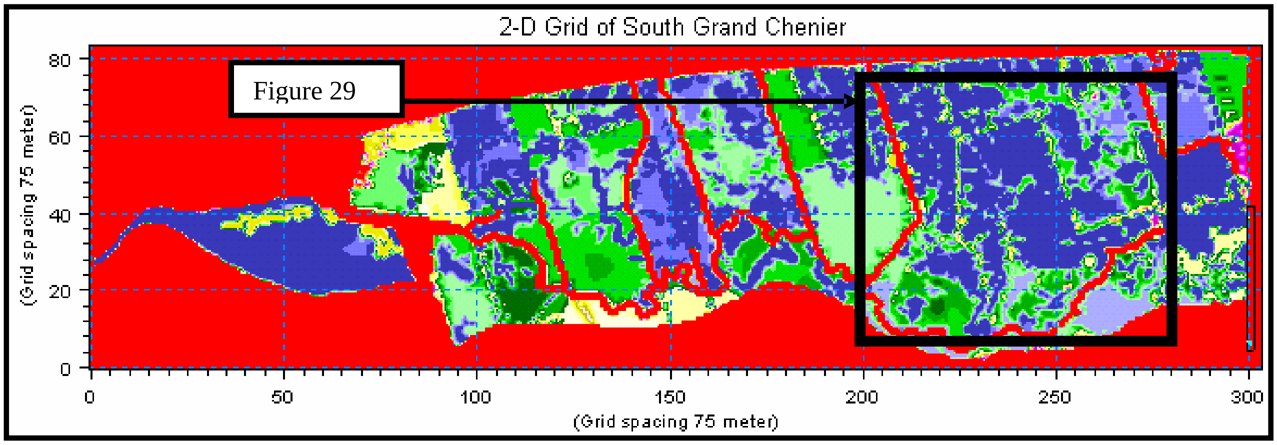


Figure 28: Basemap Showing The MIKE21 Model Grid.

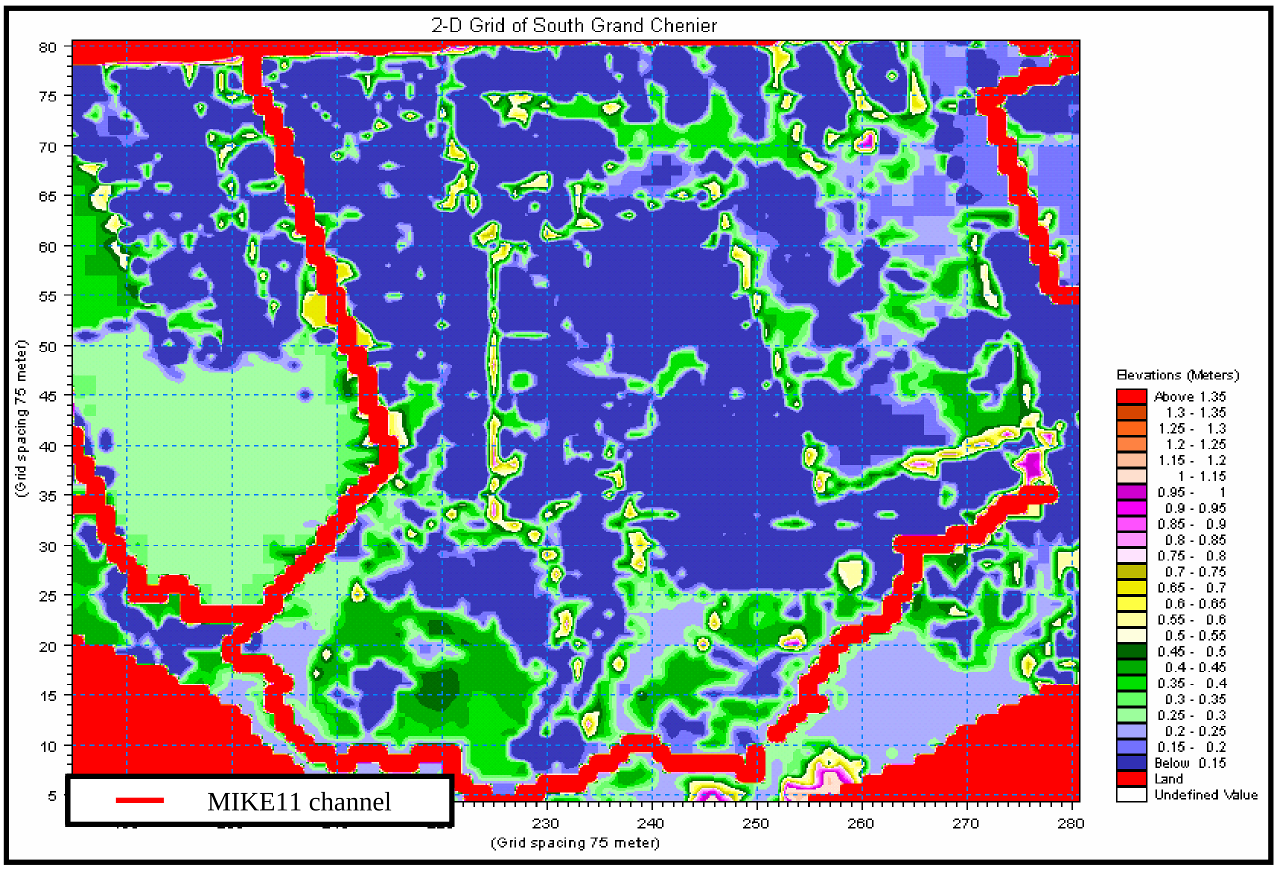


Figure 29: MIKE21 Model Grid Inset.

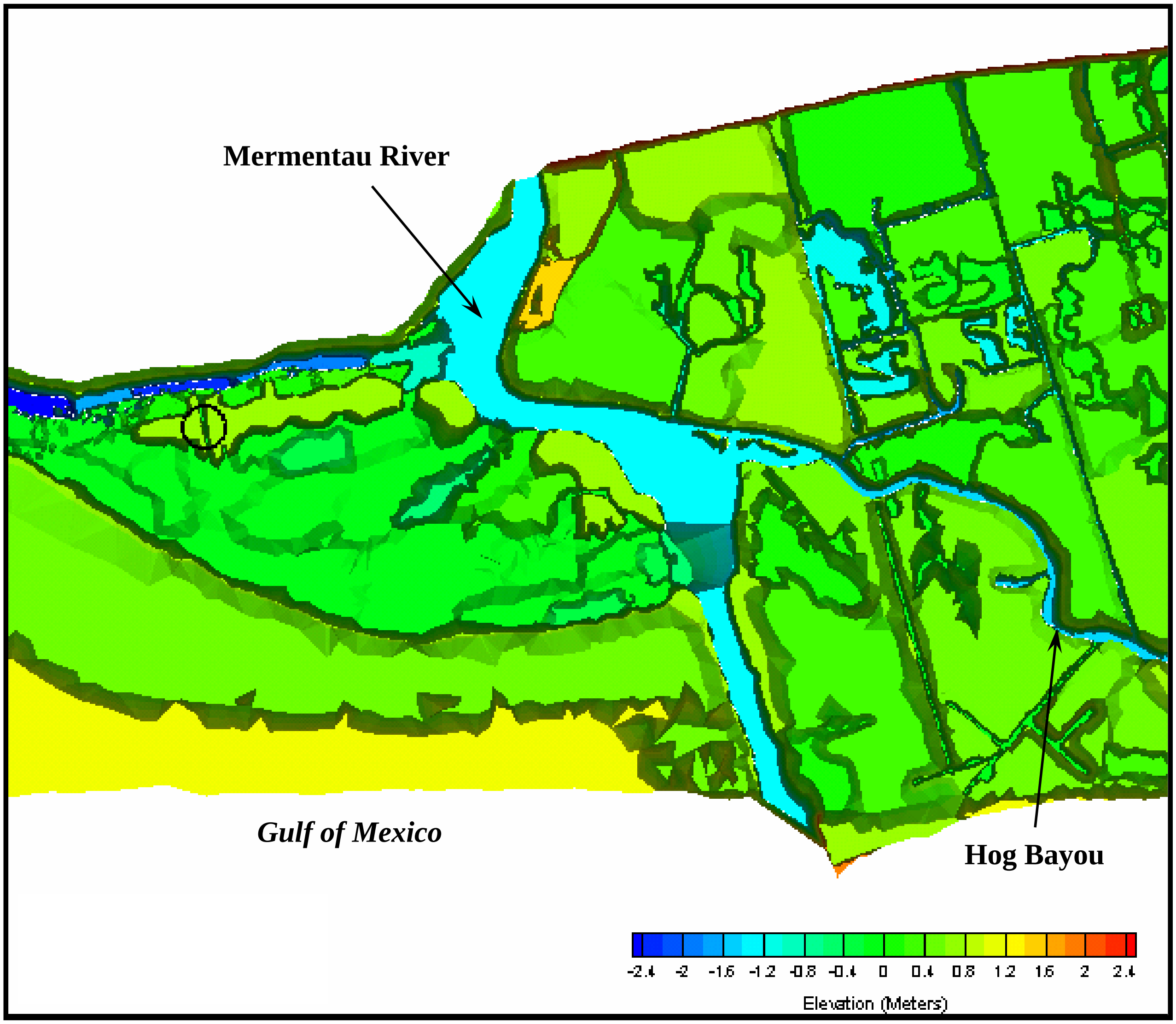


Figure 30: 3-Dimensional Visualization Of The Lower Mud Lake

An overall summary of the model setup includes:

- Over 100 miles of waterways (158 channels)
- 1,533 computational points and 69 structures (weirs, culverts with flap gates including proposed structures).
- 25,149 (250 x 250 ft) grid cells.

2.3.3 PROCESSING OF SURVEYING DATA

The modeling team at C.H. Fenstermaker & Associates, Inc. developed a FORTRAN program to process the raw survey cross-section data used to create the model. The computer program uses the following information as input:

- The raw survey data.
- The channel names from the network file of MIKE11.
- The NAD83 (North American Datum of 1983) coordinates of each computational point, the name of the branch to which it belongs, and its location (chainage) along that branch.

The program then performs the following operations:

- Through the knowledge of the coordinates of the computational points and the coordinates of the start and end points of the cross section, the program assigns each cross section to the appropriate channel.
- Corrects any misalignments in the raw survey data for each cross section.

In essence, the program converts the raw survey data directly to a format readable by MIKE 11. In addition to saving effort and time spent on processing the survey data, this program eliminates the potential human error introduced during manipulating the raw survey data. Figure 31 below illustrates an output file from the FORTRAN program that can be imported directly to the MIKE 11 software.

```
SURV2002
HUMBLE CANAL
   6022.370
COORDINATES
2  861583.58  132364.81  861681.84  132358.43
FLOW DIRECTION
 0
DATUM
 0.00
RADIUS TYPE
 0
DIVIDE X-Section
 0
SECTION ID
62
INTERPOLATED
 0
ANGLE
 0.00
PROFILE  40
   0.00    0.451.00 <#1> 0 0.00
  14.30    0.231.00 <#0> 0 0.00
  17.43    0.161.00 <#0> 0 0.00
  19.76    0.041.00 <#0> 0 0.00
  22.21   -0.031.00 <#0> 0 0.00
  24.35   -0.131.00 <#0> 0 0.00
  27.57   -0.331.00 <#0> 0 0.00
  29.70   -0.511.00 <#0> 0 0.00
  31.51   -0.701.00 <#0> 0 0.00
  32.93   -0.871.00 <#0> 0 0.00
  34.75   -1.061.00 <#0> 0 0.00
  36.35   -1.301.00 <#0> 0 0.00
  37.63   -1.381.00 <#0> 0 0.00
  39.36   -1.591.00 <#0> 0 0.00
  40.52   -1.921.00 <#0> 0 0.00
```

Figure 31: Program Output Of Cross Section Data In MIKE11 Format

2.3.4 MODEL BOUNDARY CONDITIONS

The locations of the model boundaries are shown in Figure 32. A time series of hourly field measurements for water level and salinity is used as the boundary condition at each of these locations. Information relative to how the data was collected, reference datum, etc., is found in Section 2.2.2.

2.3.5 MODELING OF HYDRAULIC STRUCTURES & MANAGEMENT PLAN

There are numerous existing and proposed hydraulic structures within the project area that needed to be carefully modeled. The existing hydraulic structures found within the project site include:

- <u>Earthen plugs</u>. These types of structures are fairly easy to model as long as the top and invert elevations of the plug is known, and the width;

- <u>Rock weirs</u>. These types of structures are also fairly easy to model if the invert elevation and the dimensions are known. The flow over a broad crested weir is determined by the head differential between upstream and downstream water levels, the geometry of the weir, and head losses. There are two regimes for flow over weirs (in addition to the trivial case of zero flow when the water levels are lower than the weir crest). These regimes are submerged or drowned flow, and free flow. Drowned flow, as the name indicates, occurs when the weir is submerged, i.e., when the flow is influenced by both the upstream and downstream water levels. The flow over a submerged or drowned weir can be expressed as follows:

$$Q = \mu b(h_1 - Z_c)(h_1 - h_2)^{1/2}$$

Where μ is the weir discharge coefficient
h_1 is the upstream water level
h_2 is the downstream water level
Z_c is the weir crest elevation

Free overflow, on the other hand, is controlled only by the upstream water level. The following equation (in System International, SI, units) can be used to describe a free flowing weir:

$$Q_c = \alpha_c 1.705 b H_s^{3/2}$$

Where α_c is the free overflow factor (a default value of 1.0 was used herein)
H_s is the available energy head above the weir crest

For all the weirs modeled here, an entrance head loss factor of 0.5 and an exit head loss factor of 1.0 were used;

- Variable crested weir. These types of structures are modeled as “control” structures. Knowledge of controlling factors for adjusting the crest elevation is required. MIKE11 requires a relationship between the controlling factor and the weir crest elevation;

- Culvert with flap gates. These types of structures are conceptually simple to model once the dimensions of the culvert barrels and the orientation of the flap gates are known. The energy losses from the entrance, exit, friction, and obstacles such as bends, trapped debris, should be incorporated into the model. Entrance and expansion losses are dependent on the inlet and outlet geometries. The more streamlined and rounded the inlet and outlet geometrics are, the less the energy losses. Numerically, these losses are coefficients that are usually fine-tuned during the calibration procedure. Losses due to the presence of flap gates were not explicitly accounted for. However, these losses were lumped together with other losses (such as entrance and exit losses), i.e. the flap gates losses were implicitly accounted for.

There are several regimes of flow through culverts depending on the upstream and downstream water levels and geometric characteristics of the inlet and exit of the structure. A brief description of the flow through culverts is described below:

Critical flow at the culvert outlet:

$$Q_c = \alpha_c A_c \sqrt{g \frac{A_c}{T}}$$

Orifice flow at the culvert inlet:

$$Q_o = \alpha_c C_o A_{full} \sqrt{2g(H_1 - z_{inv_1})}$$

Full culvert flow with free outflow:

$$Q_p = A_{full} \sqrt{\frac{2g(H_1 - z_{obv_2})}{\varsigma_1 + \varsigma_f + \varsigma_b + 1}}$$

Where

α_c is the critical flow correction factor
C_o is the coefficient of discharge
Ac is the critical flow area
T is the flow width at the water surface

A_{full} is the full cross-section area of the culvert
H_1 is the approach flow energy level
z_{inv_1} is the inflow invert level
z_{obv_2} is the outflow obvert (soffit) level (i.e. invert plus culvert depth)
ζ_1 is the contraction loss coefficient
ζ_2 is the expansion loss coefficient
ζ_f is the friction loss coefficient

Friction losses along the culvert barrel length are accounted for using the conventional Manning's roughness coefficient. All other losses, including culverts with curved barrels, debris, and any obstacles, are accounted for in the bend loss coefficient. An entrance head loss factor of 0.5, an exit head loss factor of 1.0, Manning's roughness coefficient of 0.026 (value determined from Manning's roughness coefficient for corrugated steel pipe), and a coefficient of discharge of 0.65 were used in the model. All existing culverts are made of corrugated steel pipe. All proposed culverts are assumed to be made of corrugated steel pipe.

2.3.6 MODELING OF STORAGE AREAS WITHIN THE MODEL DOMAIN

Flood plains or storage areas in a coastal hydrologic system have a dampening affect on tidal surges and salinity spikes. Therefore, it is important to account for these storage areas in any modeling effort of coastal wetland systems. One-dimensional models cannot describe in detail the flow pattern in flood plains. There are modeling techniques, however, that can be used to incorporate the impact of storage areas in one-dimensional models. Off-stream storage areas are modeled using volumetric balance. The storage-elevation relationship derived from a contour map for each storage area is entered in the cross-section editor in MIKE11. From this relationship the storage volume can be determined as a function of the elevation of the channel to which the storage area is connected. In this project however, MIKE11 was used strictly for the channels, and was dynamically linked to MIKE21 to model the marsh areas and the open water lakes and ponds. Using the two dimensional model MIKE21 ensures accurate representation of the circulation patterns, inundation, and the salinity distribution of the marsh area.

2.4 MODEL CALIBRATION

Model calibration is defined as "fine tuning of parameters until the numerical model produces results that mimics the field measurements within an acceptable tolerance." These parameters may include bed-roughness coefficients, losses through hydraulic structures, diffusion coefficients, etc. The fine-tuning of these parameters should be physically based. In other words, numerical values assigned to these parameters should remain within the established range as documented in existing literature. A brief background about each calibration parameter is provided herein:

- **Friction Coefficient**

  A) 1-Dimensional model:
  The channel's beds and banks and the marsh's surface cause friction losses to the energy of water flow. In the context of one-dimensional modeling, these losses are taken into account by the friction slope term in the momentum equation. In MIKE11, the bed-resistance term in the momentum equation is described as follows:

  $$\frac{g\,\mathrm{n}^2\,\mathrm{Q}|\mathrm{Q}|}{A\,\mathrm{R}^{4/3}}$$

  Where g is the gravitational acceleration, Q is the discharge, A is the cross sectional flow area, R is the hydraulic radius, and n is Manning's friction coefficient. The Manning n coefficient is used as one of the calibration parameters.

  B) 2-Dimensional model:
  The Bed Resistance in the context of the 2D model is described as:

  $$\frac{g\,\mathrm{u}|\mathrm{u}|}{\mathrm{C}^2}$$

  Where g is the gravity, u is the velocity and C is the Chezy number.

- **Dispersion Coefficient**:

  A) 1-Dimensional model:
  The one-dimensional equation for conservation of mass of a constituent in solution (such as temperature, salinity, etc) can be expressed as follows:

  $$\frac{\partial AC}{\partial t}+\frac{\partial QC}{\partial x}-\frac{\partial}{\partial x}\left(AD\frac{\partial C}{\partial x}\right)=-AKC+C_2.q$$

  Where C is concentration (arbitrary unit), D is the dispersion coefficient, K is a linear decay coefficient, q is the lateral inflow, and C_2 is source/sink concentration.

  The dispersion coefficient is related to the cross sectional average velocity via the following relationship:

  $$D=aV^b$$

Where a and b are constants to be specified and they can be considered as additional calibration parameters.

B) 2-Dimensional model:

The mass conservation equation in two-dimensions for dissolved or suspended solids is given by:

$$\frac{\partial(hc)}{\partial t}+\frac{\partial(uhc)}{\partial x}+\frac{\partial(vhc)}{\partial x}=\frac{\partial}{\partial x}h*D_x*\frac{\partial c}{\partial x}+\frac{\partial}{\partial y}\left(h*D_y*\frac{\partial c}{\partial x}\right)-F*h*c+S$$

Where c is the compound concentration (arbitrary units), u, v are the depth-averaged horizontal velocity components in the x, y directions (m/s), h is the water depth (m), D_x, D_y are the dispersion coefficients in x, y directions (m^2/s), F is the linear decay coefficient (sec^{-1}), S = Q_s (c_s-c), Qs is the source/sink discharge $m^3/s/m^2$ and c_s is the concentration of compound in the source/sink discharge Q_s. Information on u and v are provided from the hydrodynamic module.

- **Mixing Coefficient**:

  At an outflow (flow is leaving the numerical model domain) boundary, the concentration at the boundaries is calculated based on the concentration at the points neighboring that boundary, even if there is a time series of salinity concentration specified at that boundary. At an inflow (flow is entering the numerical model domain) boundary, the concentration at the boundary is calculated as follows:

$$C = C_{bf} + \left(C_{out} - C_{bf}\right)e^{-t_{mix}K_{mix}}$$

  Where C_{bf} is the boundary concentration specified in the time series file, C_{out} is the concentration at the boundary immediately before the flow direction changed (from outflow to inflow), K_{mix} is the time-scale mixing coefficient, and t_{mix} is the time since the flow direction changed.

The model was calibrated for the field data in the time period between November 01, 2002 and January 01, 2003. The following list shows values assigned to each of the aforementioned parameters used to calibrate the model. These values produced a good match between the model results and the field data.

- Manning's Friction Coefficient: 0.033-0.05 *
- Mixing Coefficient K_{mix}: 0.5
- Dispersion Coefficient (1D):

---

* Equivalent composite value (channel and marsh roughness)

- Dispersion factor a: 1.0
- Dispersion exponent b: 0.0

- Dispersion Coefficient (2D):
  - X-Direction: 0.25
  - Y-Direction: 0.25
- It should be noted that the dispersion coefficient range in the 1-dimensional model was limited to a maximum of 100 m^2/s and a minimum of 1 m^2/s.

The model calibration results for salinity and water level are shown below in Figures A-1 through A-6 (located in the Appendix). It should be noted that there is uncertainty associated with the field measurements. It is important to understand, and whenever possible quantify these uncertainties. Aside from the accuracy limits of the sensors used in the continuous recorders, residue always builds up on the recorders and affects their accuracy. To quantify the impact of this build up, a reading of the sensor prior and after the periodic cleaning is recorded. The field personnel use the difference between the two readings to apply a linear correction to the record since the previous download of data. However, applying a linear correction to account for the build up of residue is only an assumption and may introduce an error. Another issue that should be stated herein is that the salinity measurements were collected at singular points. In other words, neither transverse profiles, nor vertical profiles of salinities were available to estimate cross sectional average salinities to compare with the cross sectional average salinities produced by the numerical model within the channels. Keeping such uncertainties in mind is important, even though they could not be quantified precisely in this study.

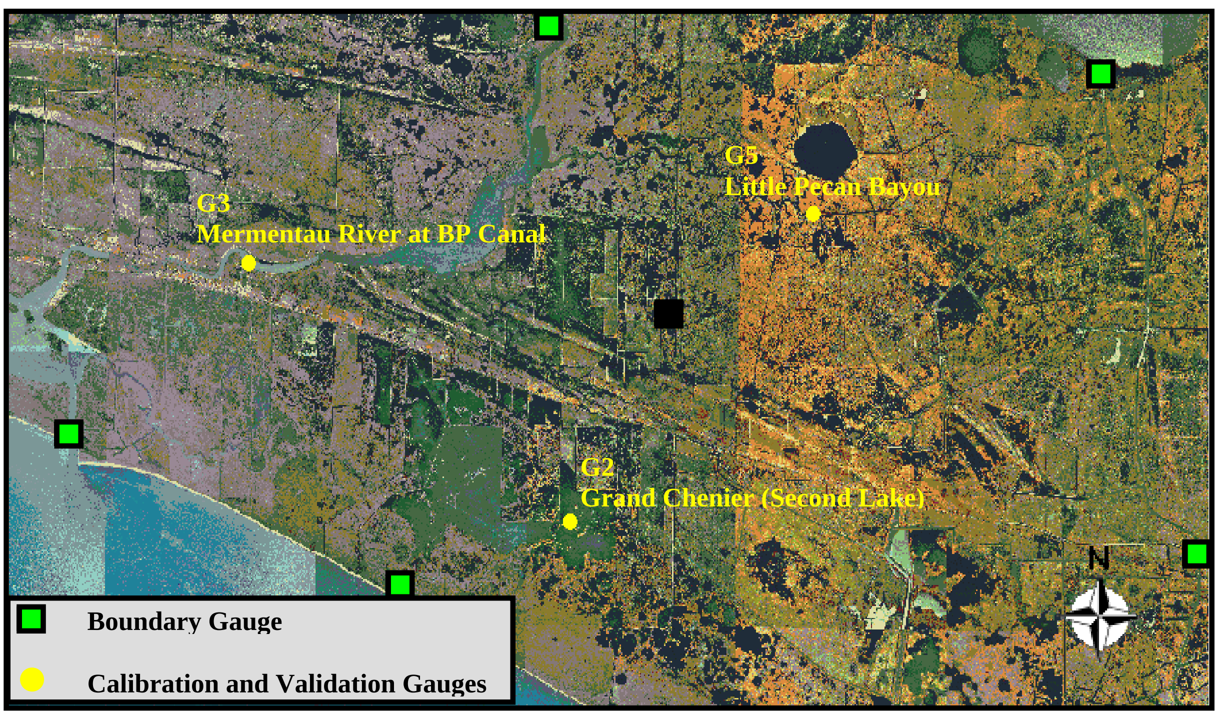


Figure 32: Location Of Boundary, Calibration And Validation Gauges

2.5 MODEL VALIDATION

2.5.1. EVALUATION OF MODEL PERFORMANCE

When the calibration process is complete, an independent data set is used to validate the model. As mentioned earlier, the model was calibrated for the field data in the time period between November 01, 2002 and January 01, 2003. The data set that was used to validate the model, which extends to April 03, 2003. A quantitative assessment of the model results is presented in Table 2:

	Salinity		
	RMS Deviation	*RMS Percent*	*Range*
Gage	(ppt)	%	(ppt)
Mermentau River G3	4.49	17.33	25.93
Little Pecan G5	1.71	40.17	4.26
2D Model G2	0.91	13.33	6.81
	Water Level		
	RMS Deviation	*RMS Percent*	*Range*
Gage	(ft)	%	(ft)
Mermentau River G3	0.40	11.73	3.42
Little Pecan G5	0.30	12.03	2.46
2D Model G2	0.31	27.36	1.13

Table 2: Quantitative Assessment of Model Results

The root mean square and Range used in Table 2 are defined as follows:

$$RMS \text{ Deviation} = \frac{1}{N}\sum_{1}^{N}\frac{\sqrt{(\text{computed - observed})^2}}{\textit{Observed} \text{ Range}}$$

Range = Max Measured value- Min Measured value

Where N is the number of hourly field observations.

There are numerous peer-reviewed publications that report comparable uncertainty levels to that presented herein, e.g. (Blumberg[1] et al, 1999, and Jin[2], 2000). The acceptable uncertainty level varies depending on the project objective. The uncertainty level for water level and salinity shown in Table 2 is acceptable for the project studied herein. These deviations can be attributed to uncertainty of bathymetry and channel dimensions,

[1] Blumberg A. F., Khan L.A., John J.P. (1999). Three-Dimensional Hydrodynamic Model for New York Harbor Region, Journal of Hydraulic Engineering, Vol. 125, No. 8.

[2] Jin K.R. (2000). Application of Three-Dimensional Hydrodynamic Model for Lake Ockeechobee. Journal of Hydraulic Engineering, Vol 126, No.10.

approximation to the impact of the storage areas on the flow and salinity patterns, uncertainties in field measurements, and numerical approximations.

The model validation results are presented as time series plots for water and salinity levels as shown in Figures A-7 through A-12 (located in Appendix). Contour maps of salinity and water levels for model validation results are shown in Figures A-13 through A-20 (located in Appendix). These maps show the spatial distribution of water and salinity levels throughout the project domain.

As can be seen from Figures A-7 through A-12 and Table 2 above, the model matches the field data reasonably well. The model can be used to evaluate the effectiveness of the proposed project features.

2.5.2. DISCUSSION OF LIMITATION AND CAPABILITIES OF THE MODEL

One-dimensional models, in general, do not provide information of salinity distribution across the width of a channel or over the water column of that channel. Rather, it provides a cross-section salinity average. A one-dimensional model assumes that the salinity is mixed over any given channel cross section. One-dimensional models, however, do provide for the changes in salinity from one station to another along the length of a channel. For this particular project, the channels are fairly small and shallow (except for the Mermentau River), therefore, flow stratification is minimal and the variation of salinity from one bank of a channel to the other is small. It is for this reason that a one-dimensional model can be used.

The salinity deviations between the model results and the raw field data in the Mermentau River can be mainly attributed to the assumption that the salinity is being fully mixed over the cross section of the channel. Since it is not the intent of this project to model the Mermentau River itself, but rather the surrounding areas, the uncertainties shown in Figure A-10 are acceptable for this project. In Figure A-10, the model was able to follow the general trends, however, the model did miss high-frequency fluctuations.

The two-dimensional model is capable of providing detailed water level and salinity spatial information over the marsh. Parameters such as hydro-period and marsh salinities can be computed from the two-dimensional model results. Overall, the information provided by the numerical model is adequate to provide a reliable assessment of the project features. A detailed evaluation of the proposed project along with the suggestions and improvements to the design of the project features are provided in Chapter Three.

III. CHAPTER THREE

3.1 INITIAL ASSESSMENT OF PROJECT FEATURES

The proposed project features described in Chapter One were incorporated into the model. A detailed description of the proposed structures is shown in Figures 33 through 39.

Salinity and water level data at the locations shown in Figure 40 were examined to evaluate the effectiveness of the project features. To maintain consistency in the notation, simulation of the existing conditions (without any of the proposed project features) is referred to as the “Base Run”. The simulation that incorporates the conceptual project features is referred to as “Conceptual Design Run”.

A comparison between the “Base Run” and the “Conceptual Design Run” was performed. Model results after incorporating project features are presented as a series of time series plots for the water level and salinities as shown in Figures A-21 through A-28 (located in Appendix). Water level and salinity contour maps for both the “Base Run” and the “Conceptual Design Run” are shown in Figures A-29 through A-36 (located in the Appendix).

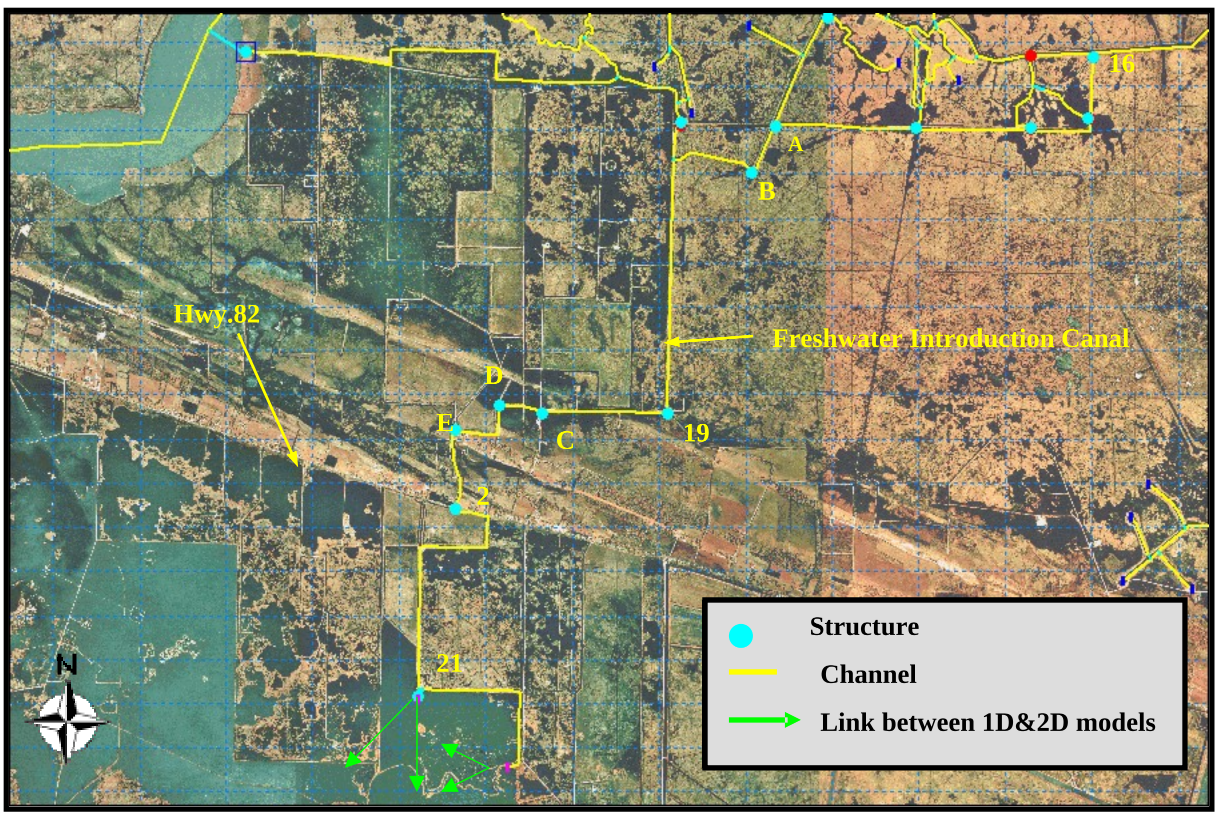


Figure 33: Modified Channel Network After Incorporating The Project Features

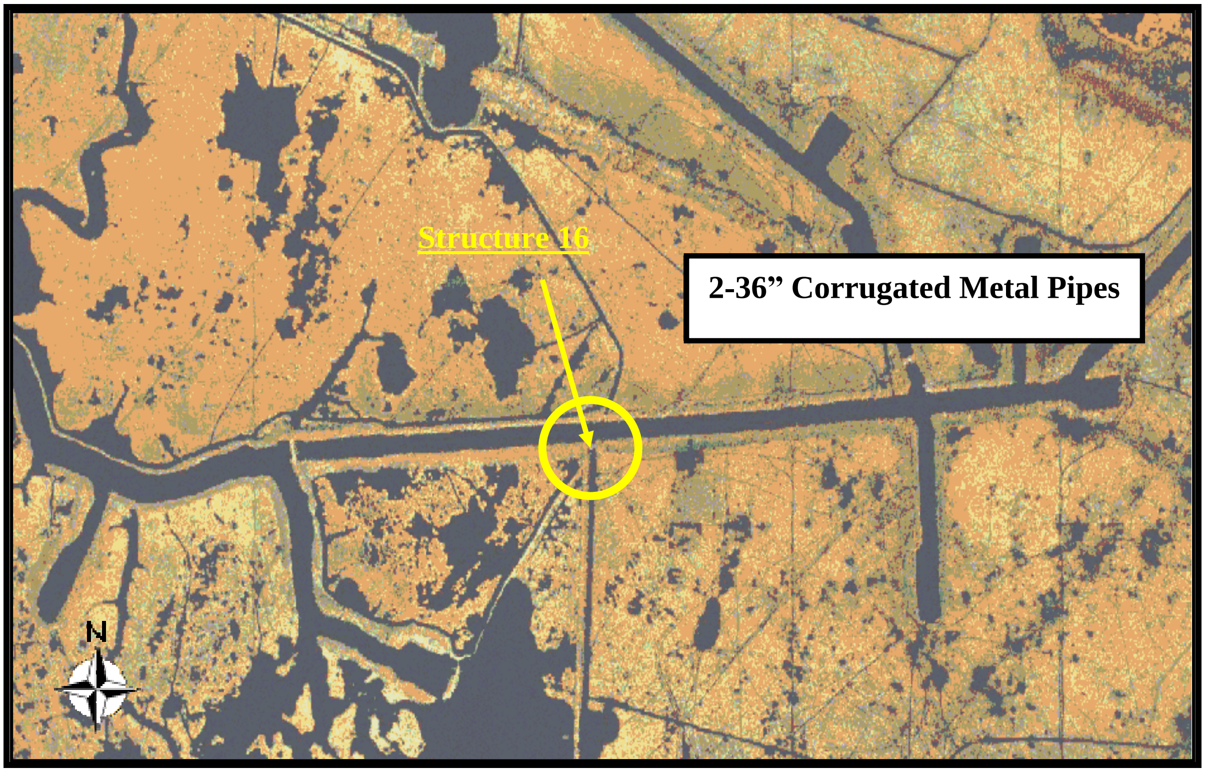


Figure 34: Structure 16 (Refer to Figure 33 for reference)

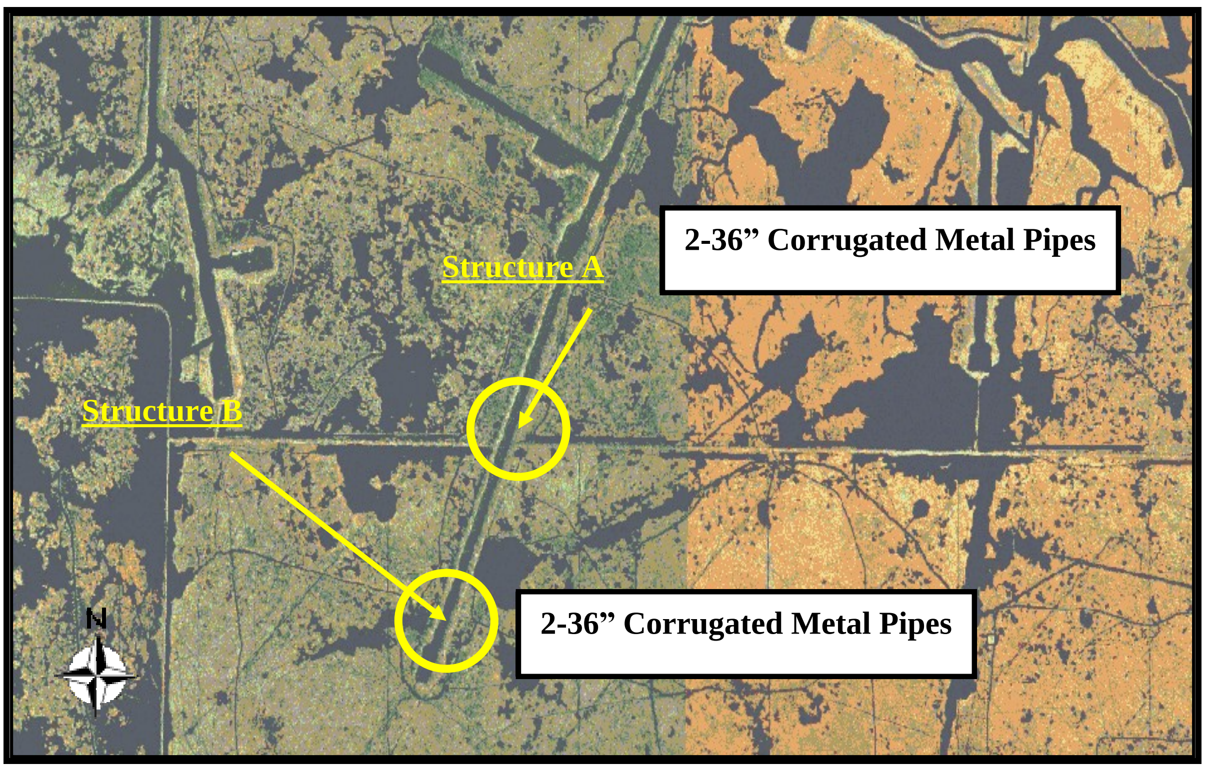


Figure 35: Structures A & B (Refer to Figure 33 for reference)

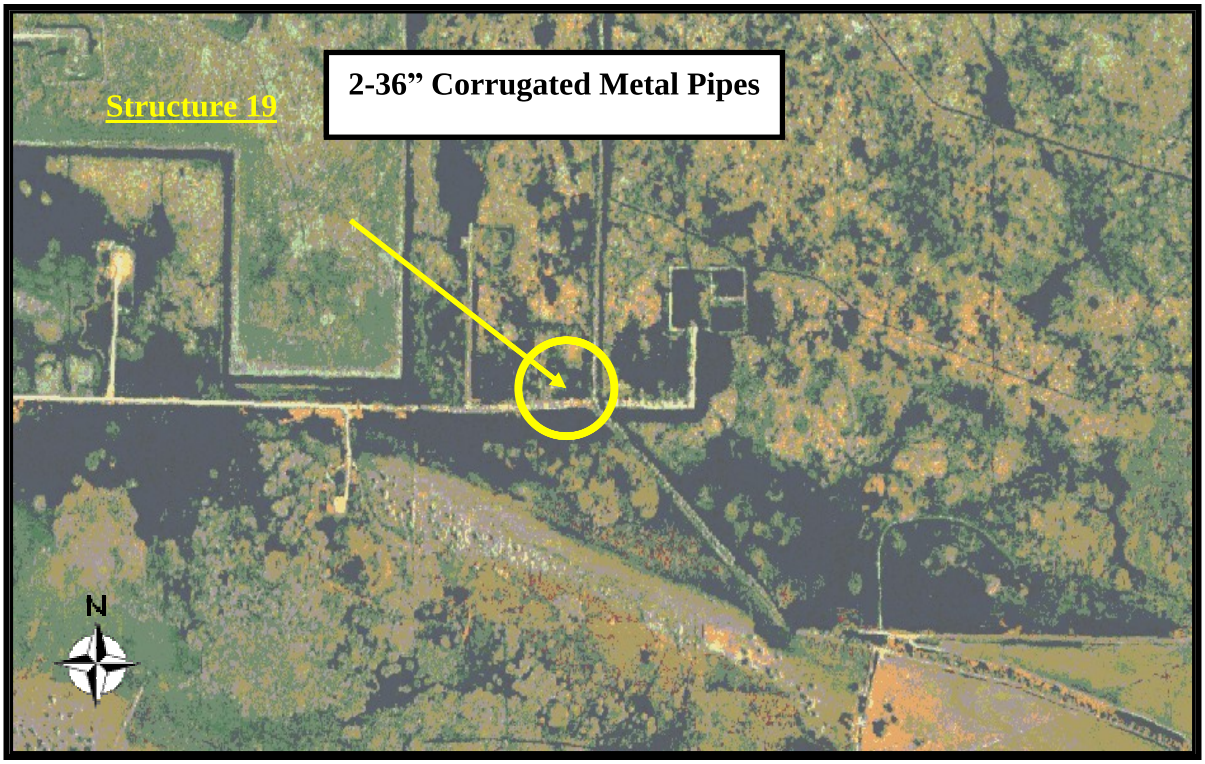


Figure 36: Structure 19 (Refer to Figure 33 for reference)

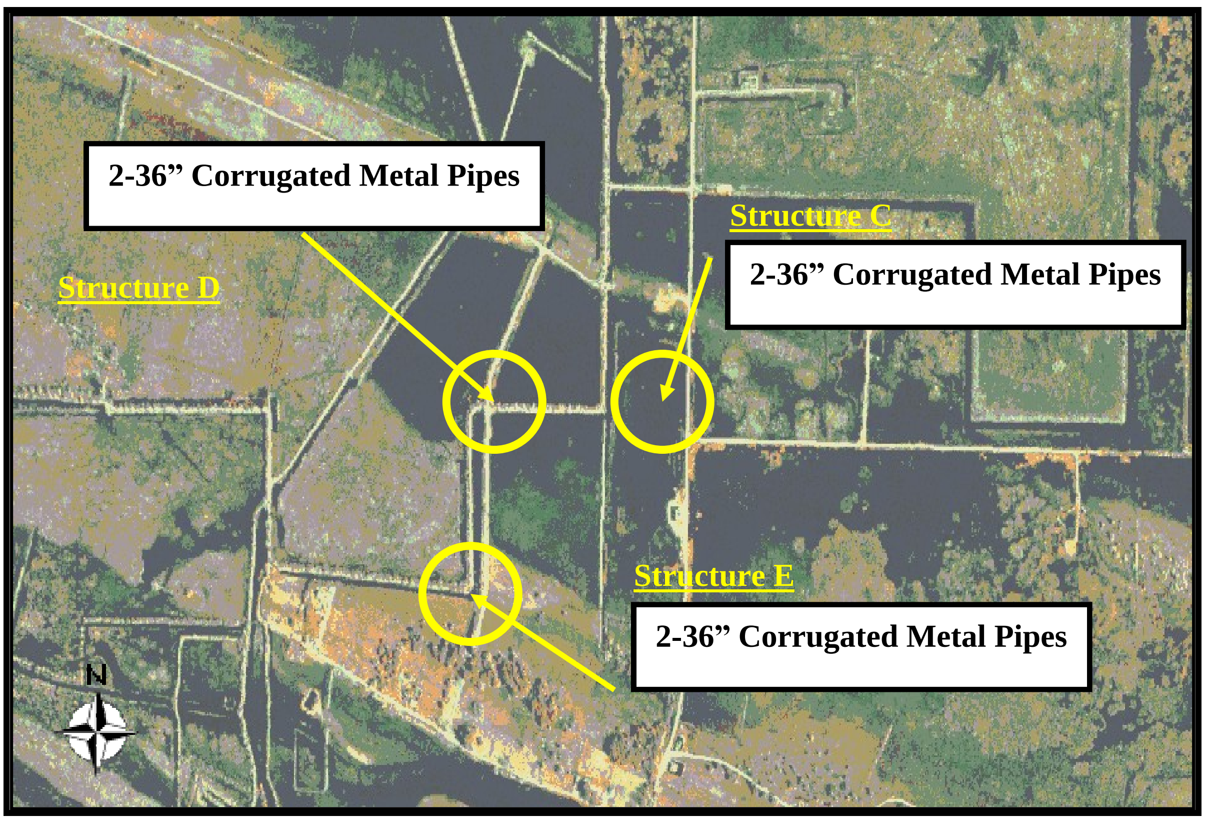


Figure 37: Structure C, D & E (Refer to Figure 33 for reference)

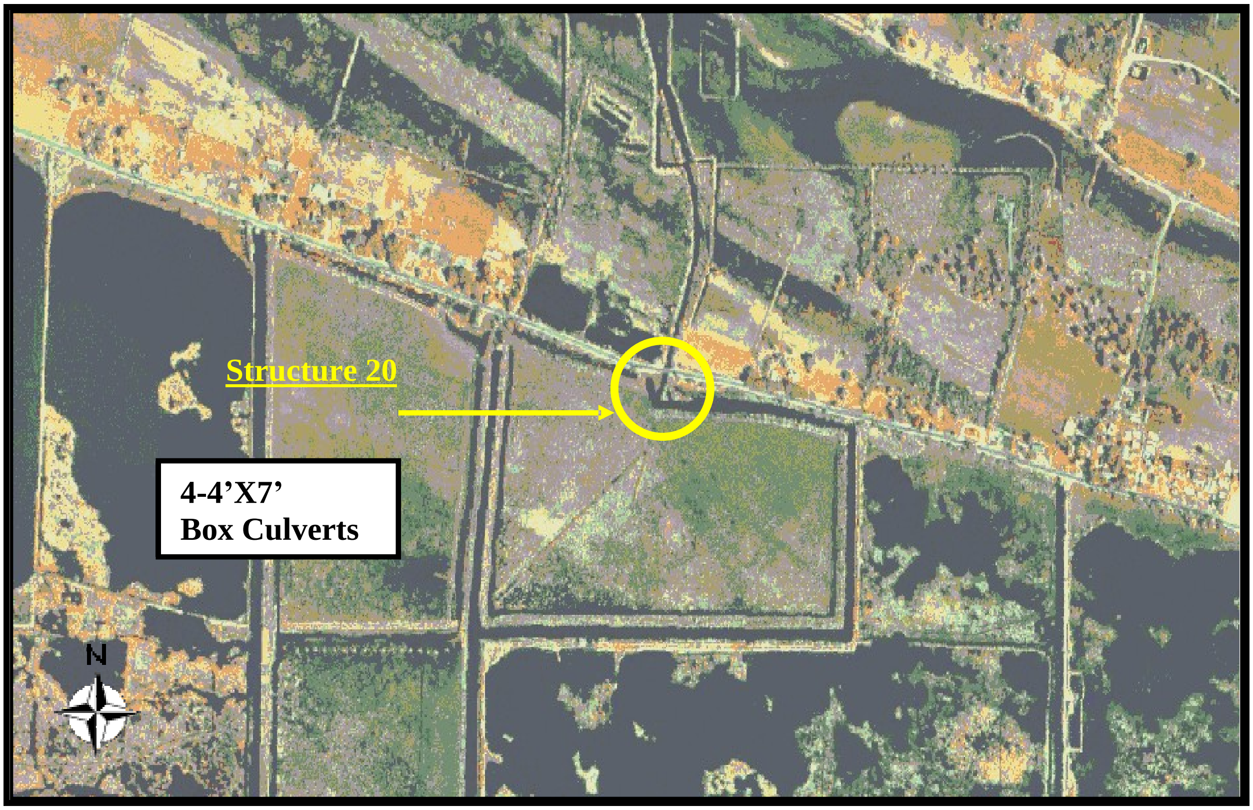


Figure 38: Structure 20 (Refer to Figure 33 for reference)

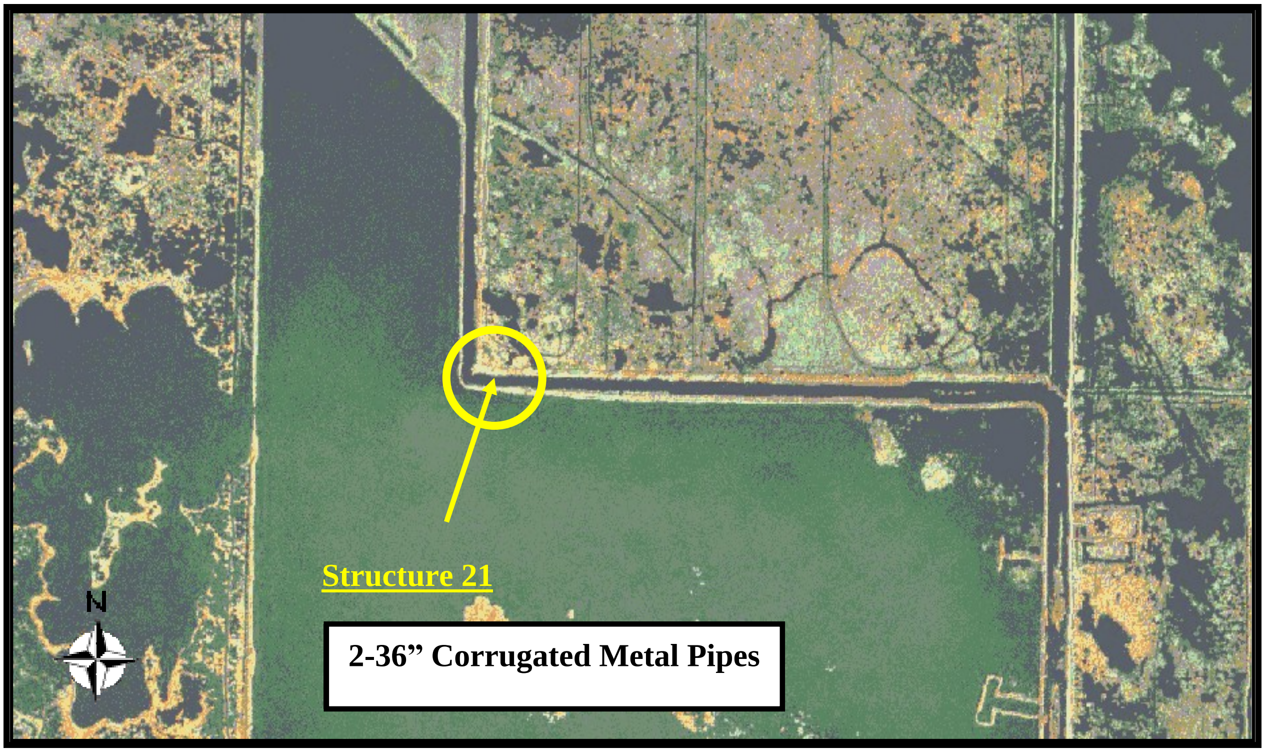


Figure 39: Structure 21 (Refer to Figure 33 for reference)

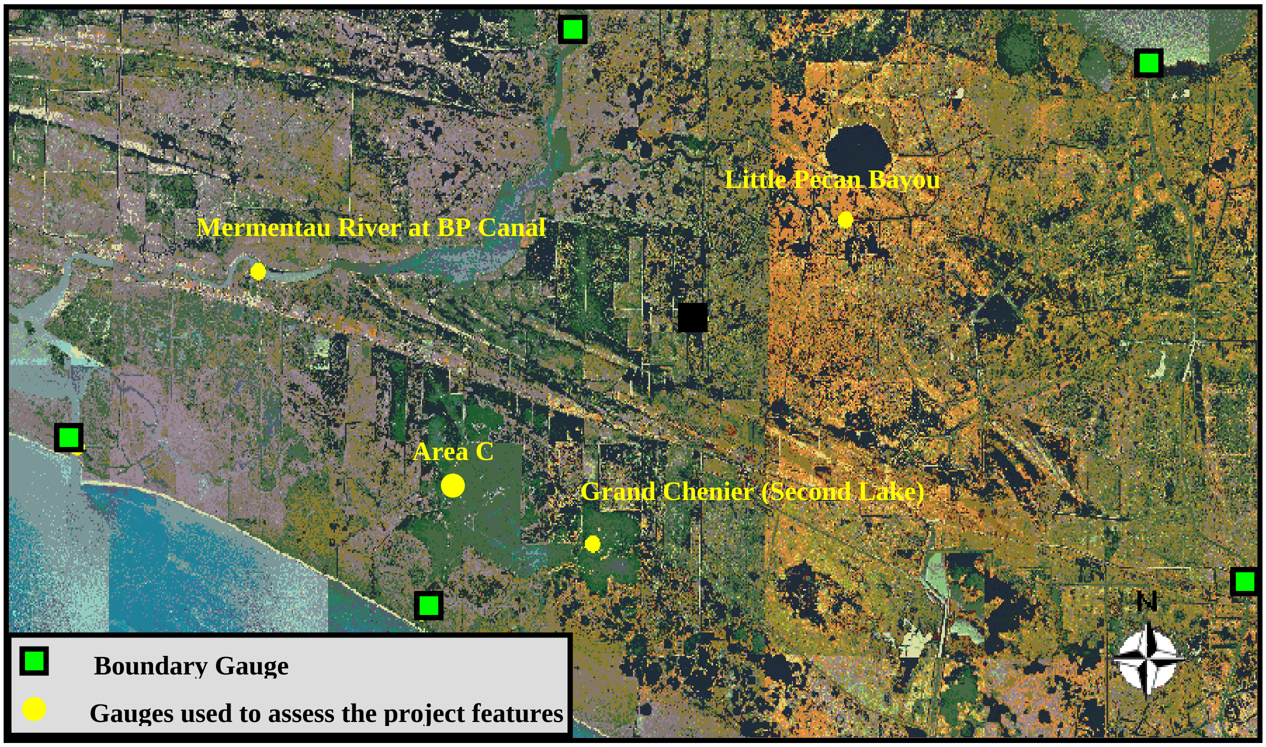


Figure 40: Basemap Showing Boundary Gauges And Gauges Used To Assess The Project Features

From the results presented in Figures A-21 through A-36 (located in Appendix), it can be seen that the project reduced salinity in Areas C and Second Lake. The magnitude of salinity reduction at these two locations ranged from one to four parts per thousand (ppt). The salinity reduction in Area C was less than Second Lake. Second Lake is adjacent to the outlet of the proposed freshwater introduction canal, while Area C, as shown in Figure 41, is separated from the introduction canal by the McCall Strulese Tract. Although the levees between Area C and the introduction canal are not fully intact, they somewhat limit the fresh water flow to the area.

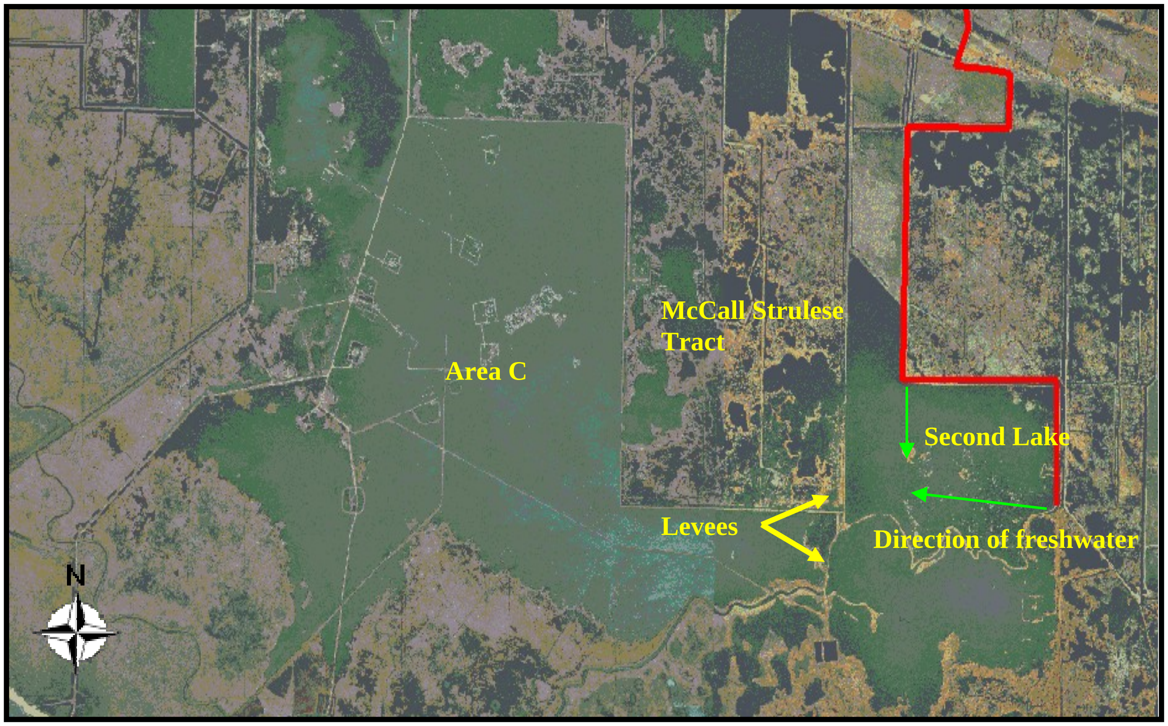


Figure 41: Direction Of Freshwater Movement

It is observed that the project features did not affect the water level or the salinity in the Mermentau River. For Little Pecan Bayou, the project features had no impact on the water level, but it did impact the salinity. This is because the freshwater coming from the superior canal through the introduction canal was able to reach the Little Pecan Bayou again as opposed to the existing conditions where the water is stopped using the existing plug shown in Figure 42. However at the validation and model results meeting held in the offices of C. H. Fenstermaker and Associates Inc. on February 02, 2004, the federal and state agencies recommended modifying the model setup to eliminate this phenomenon. The change was taken into consideration when designing the alternative model simulations as will be mentioned in section 3.2.

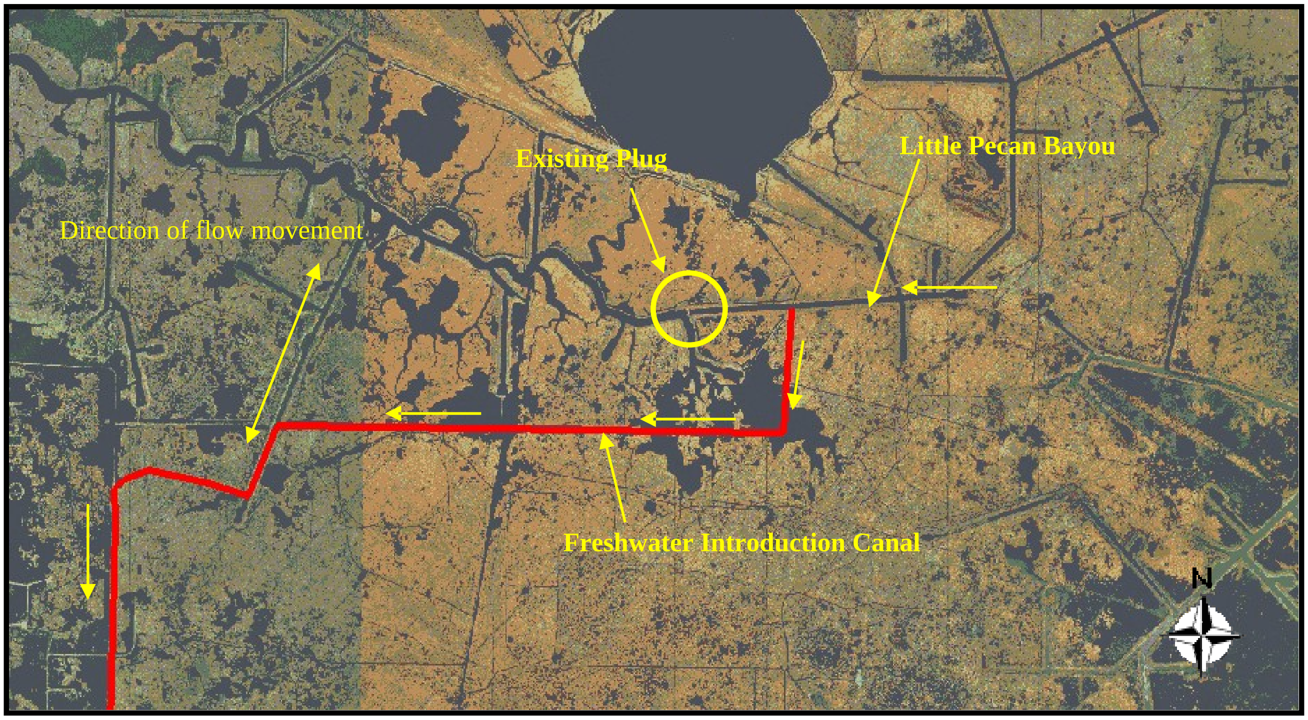


Figure 42: Direction Of Freshwater Movement.

3.2 ADJUSTMENTS TO THE CONCEPTUAL DESIGN AND NEW ADDITIONAL MODEL RUNS

On June 02, 2004, all participating parties in the project met at the offices of C.H. Fenstermaker and Associates Inc. to examine the results and to formulate a hydraulically and logistically feasible route for conveying freshwater from Grand Lake. All parties agreed that although the initial route did satisfy the objectives of the project, a new conveyance channel with a more logistically and/or hydraulically favorable alignment could produce more benefits. With this in mind, the conceptual design run will be eliminated from the scope of services of the project, and two new alignments were proposed as follows:

<u>Alignment No.1</u>

Alignment No.1 shown in Figure 43 through 45 uses an existing oil slip canal that ties into Superior Canal flowing from Grand Lake. This canal would then tie into the original alignment, bypassing the existing plug owned by Miami Corporation.

Alignment No.2

Alignment No.2 shown in Figure 46 and 47 uses an existing oil field canal just south of that used for Alignment No.1. This proposed alignment completely bypasses the portion of the original alignment that runs east/west. It is connected to an existing parallel trenasse located approximately 1600 ft south of the original alignment.

For the two alignments, two 5'X5' box culverts (see Figure 48) will be constructed at all gravel road crossings. Also a flap-gate structure would be constructed just north of LA Hwy. 82. This structure would consist of 2-5' wide gates that would stop flows from Grand Lake during long periods of rains to limit amount of water that can go to the marshes south of Highway 82 and prevent excessive ponding. Several breaches near the outlet point of the conveyance channel south of LA Hwy. 82 need to be added to the model in order to spread fresher waters further into areas of undernourished marsh (see Figures 49 and 50). Staggered levees every 500' will also have to be constructed along the route of the conveyance channel. LDNR selected to build the staggered levees as a way to prevent excessive flooding of the conveyance channel, and at the same time prevent excessive overland flow from entering the conveyance channel.

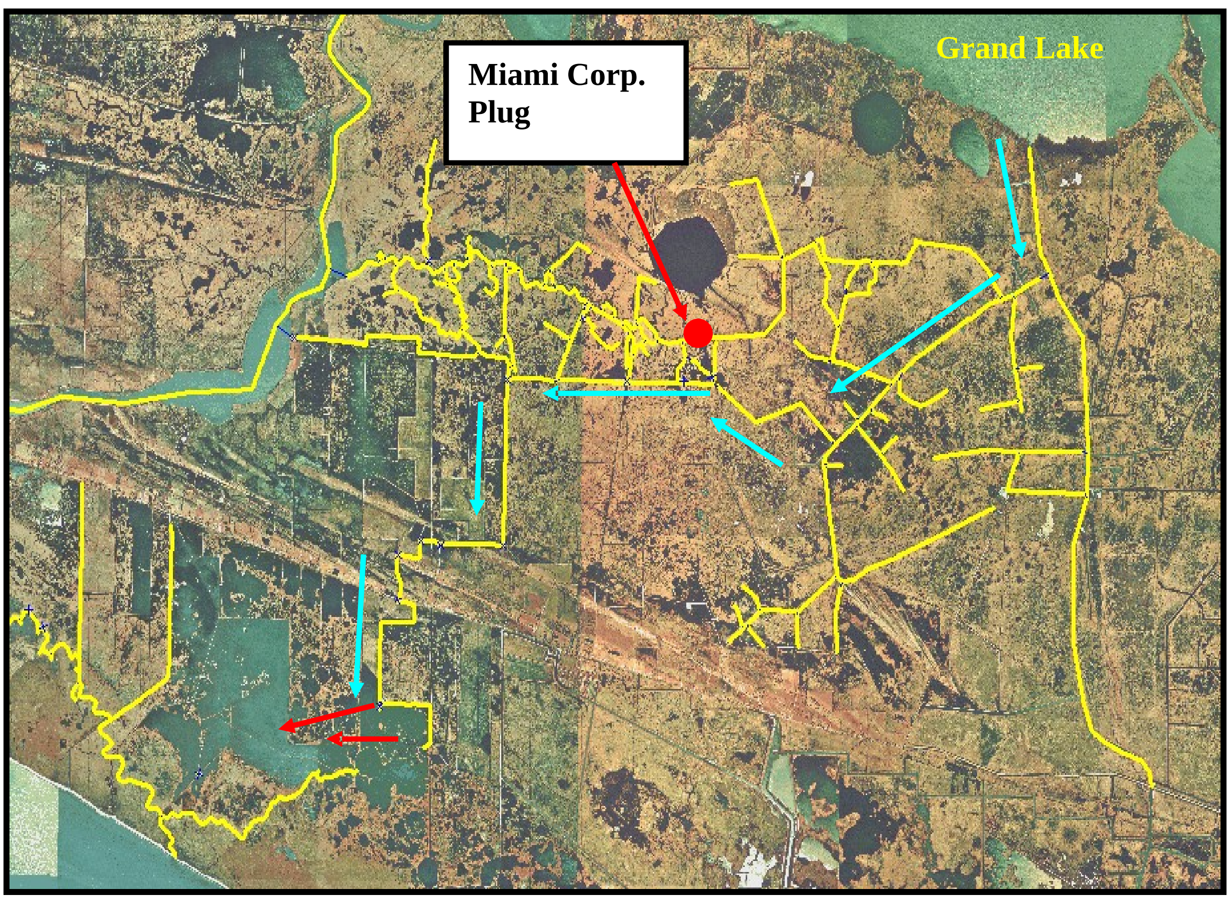


Figure 43: Proposed Alignment No.1

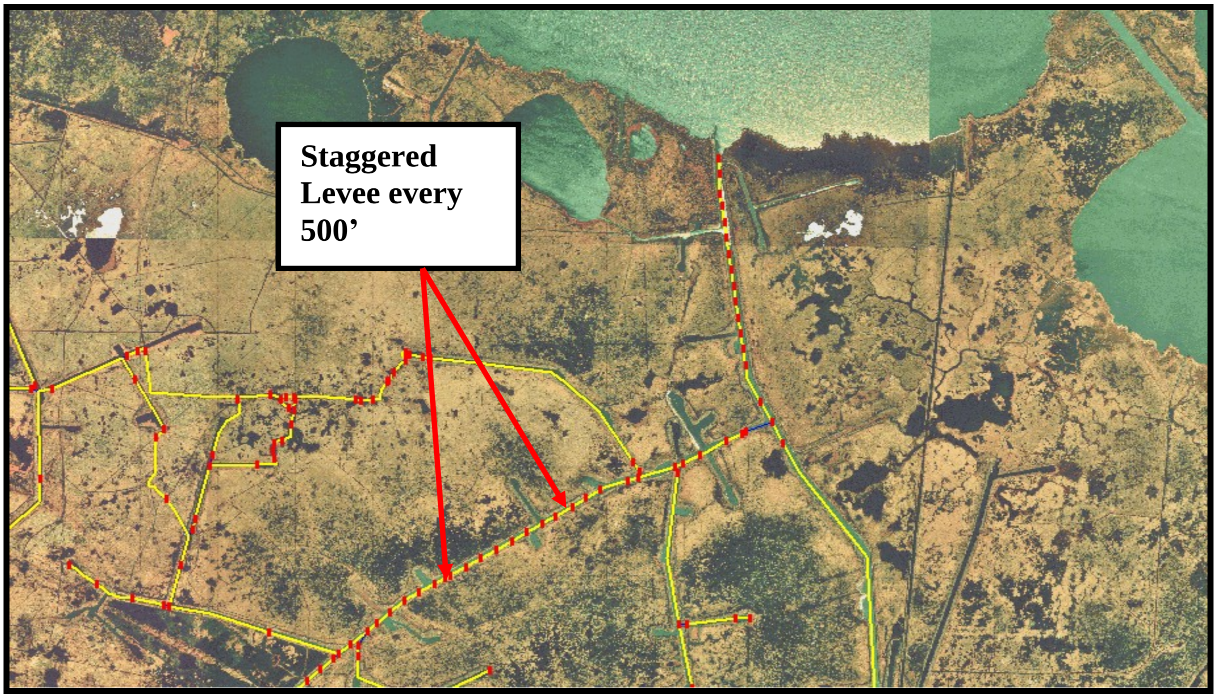


Figure 44: Staggered Levee Along The Route Of The Channel

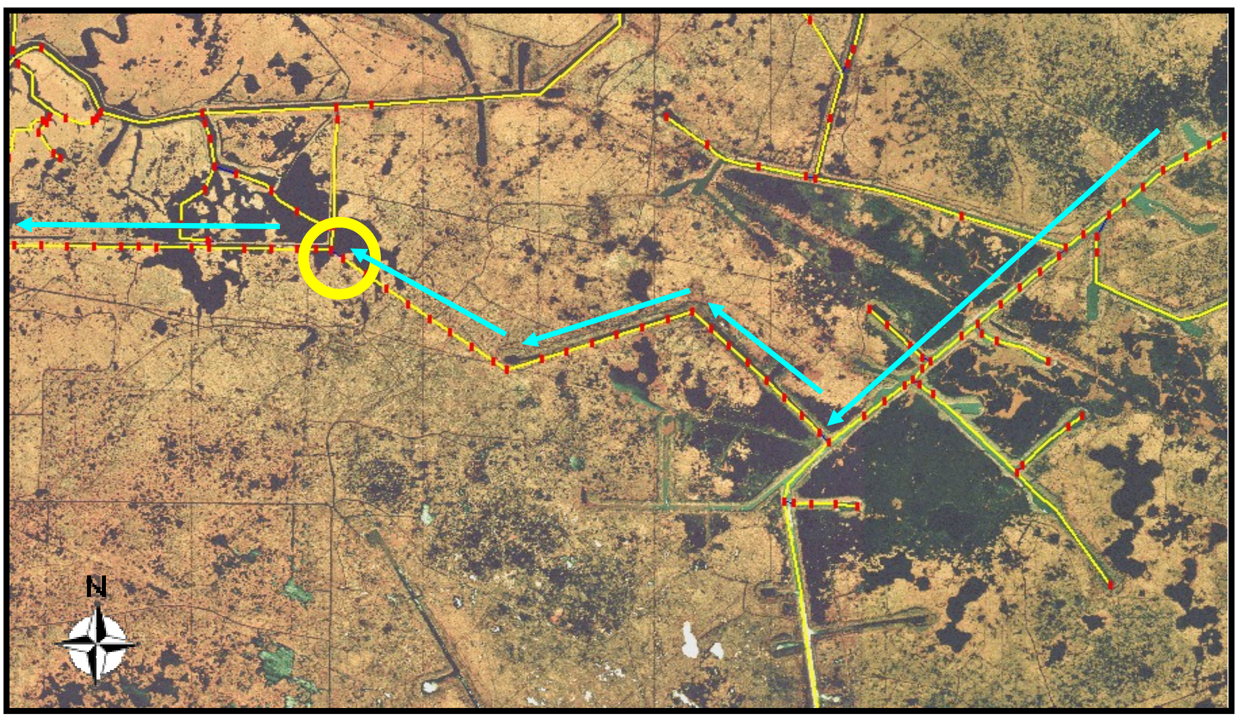


Figure 45: Proposed Alignment No.1 Connection To The Original Proposed Alignment

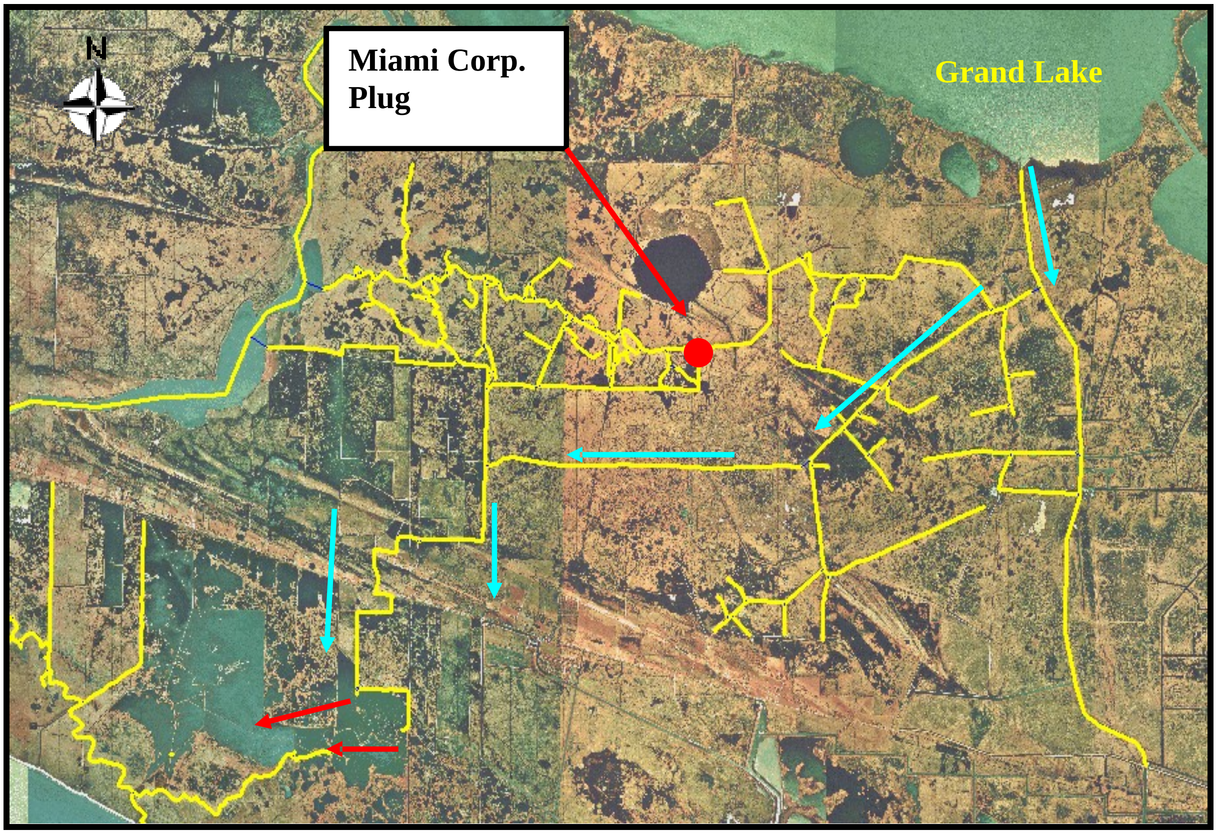


Figure 46: Proposed Alignment No.2

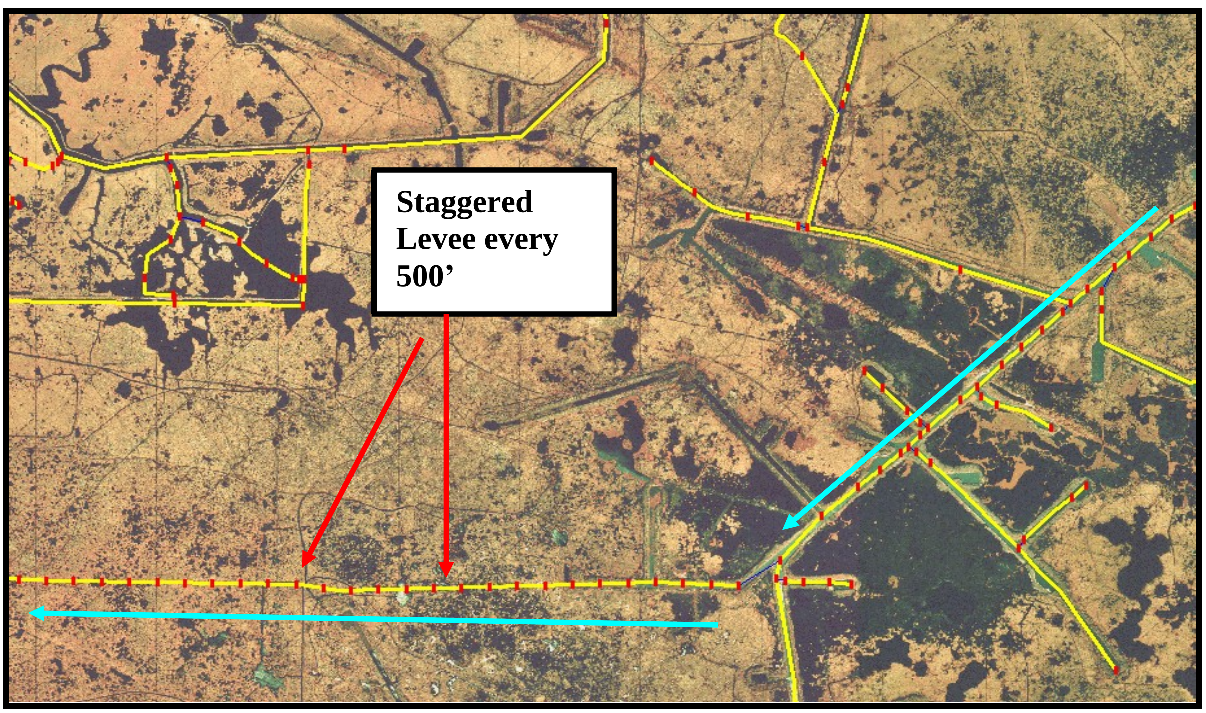


Figure 47: Proposed Alignment No.2 Route Bypassing The Original Proposed Alignment.

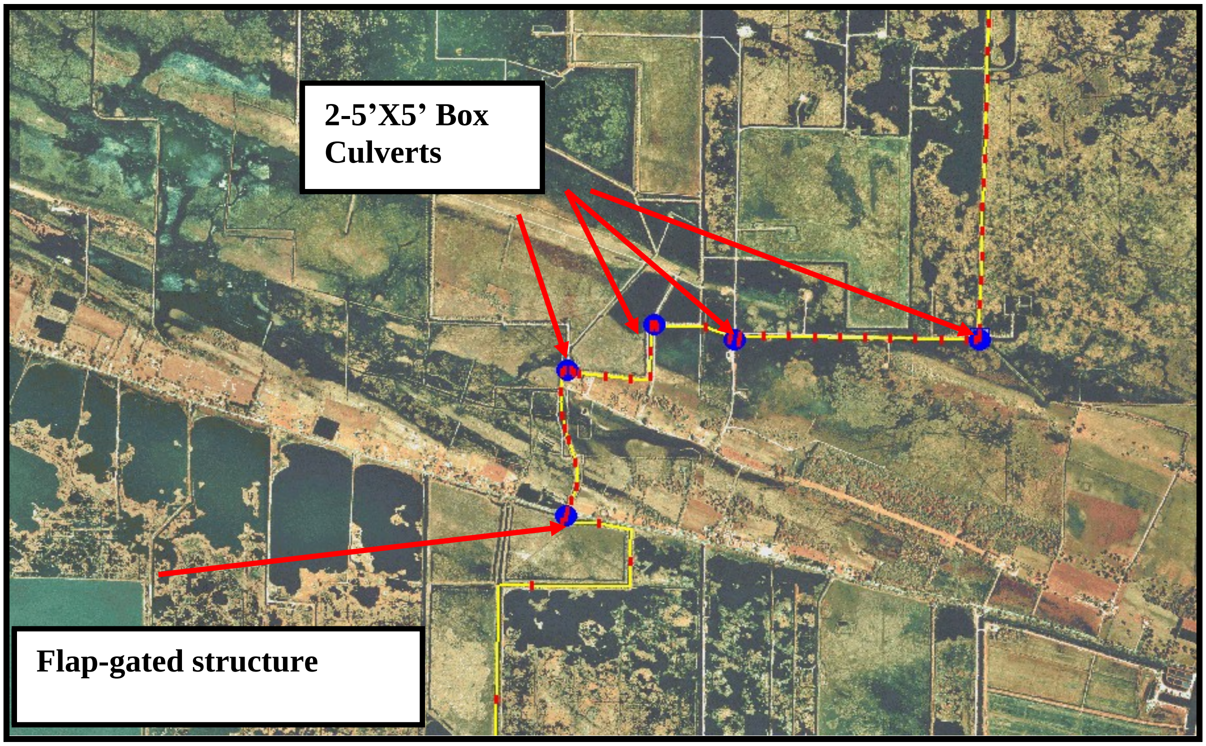


Figure 48: Proposed Structures Along The Route Of The Two Proposed Alignments.

Figure 49: Direction Of Freshwater Movement.

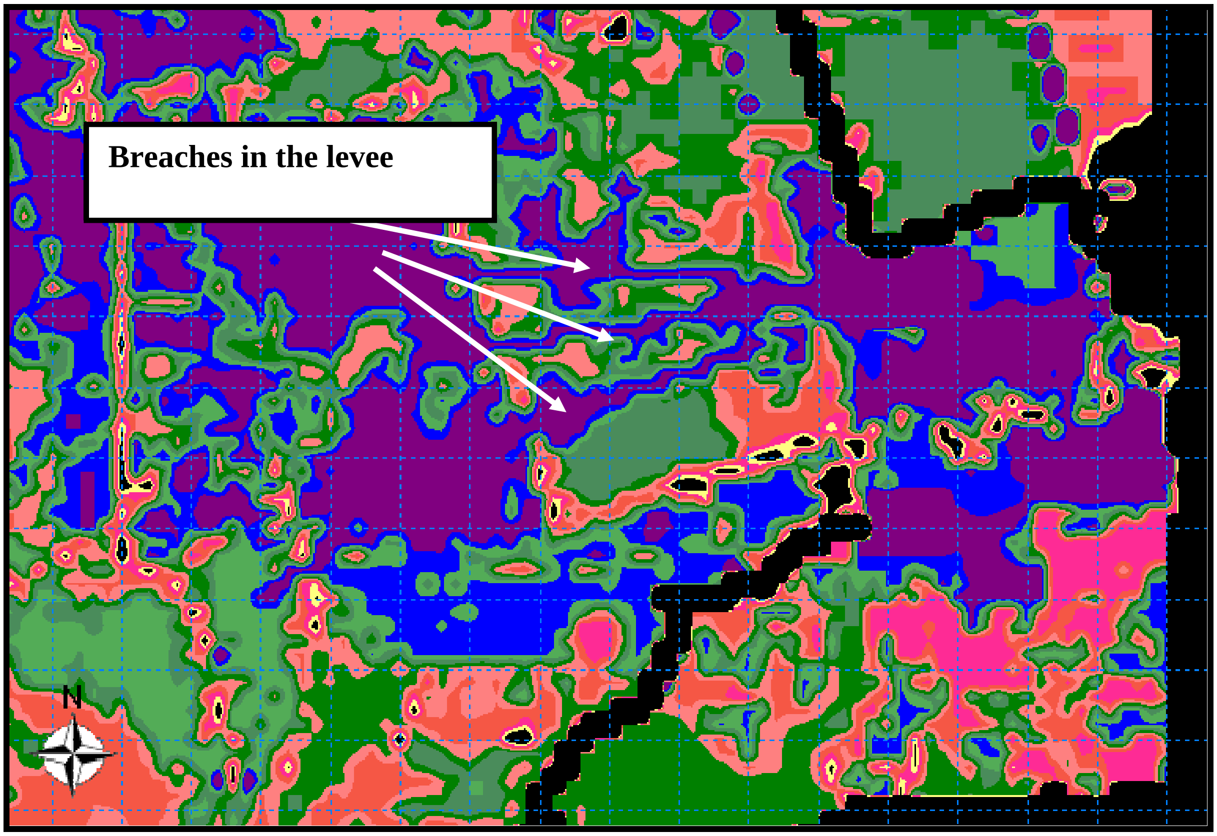


Figure 50: Breaches In The Levee To Facilitate Freshwater Movement

3.3 FINAL ASSESSMENT OF PROJECT FEATURES

Two new simulations were performed for the new proposed project alternatives. Model results are presented as time series plots for water level and salinity, as well as water level and salinity contour maps. The locations shown in Figure 51 were selected to provide an assessment of the impact of the two proposed project alternatives.

Figures A-37 through A-68 (located in Appendix) show Microsoft Excel plots to evaluate the project features. Presented in these figures is a comparison of water level and salinity between the Base Run (Existing Conditions) and the two alignments runs, as well as plots of the change in salinity and water level.

Meanwhile, to show the affect of the project on the surrounding marshes and the open water bodies, Figures A-69 through A-73 (located in Appendix) show contour maps of the monthly average water elevation for all proposed alternatives as well as the "Base Run". Figure A-74 through A-83 show contour maps of the monthly average water elevation change (Alternative Run minus Base Run) contour maps.

Figures A-84 through A-88 (located in Appendix) show contour maps of the monthly average salinity for all proposed alternatives as well as "Base Run". Figure A-89 through A-

98 (located in Appendix) show contour maps of the monthly average salinity change (Alternative Run minus Base Run) contour maps.

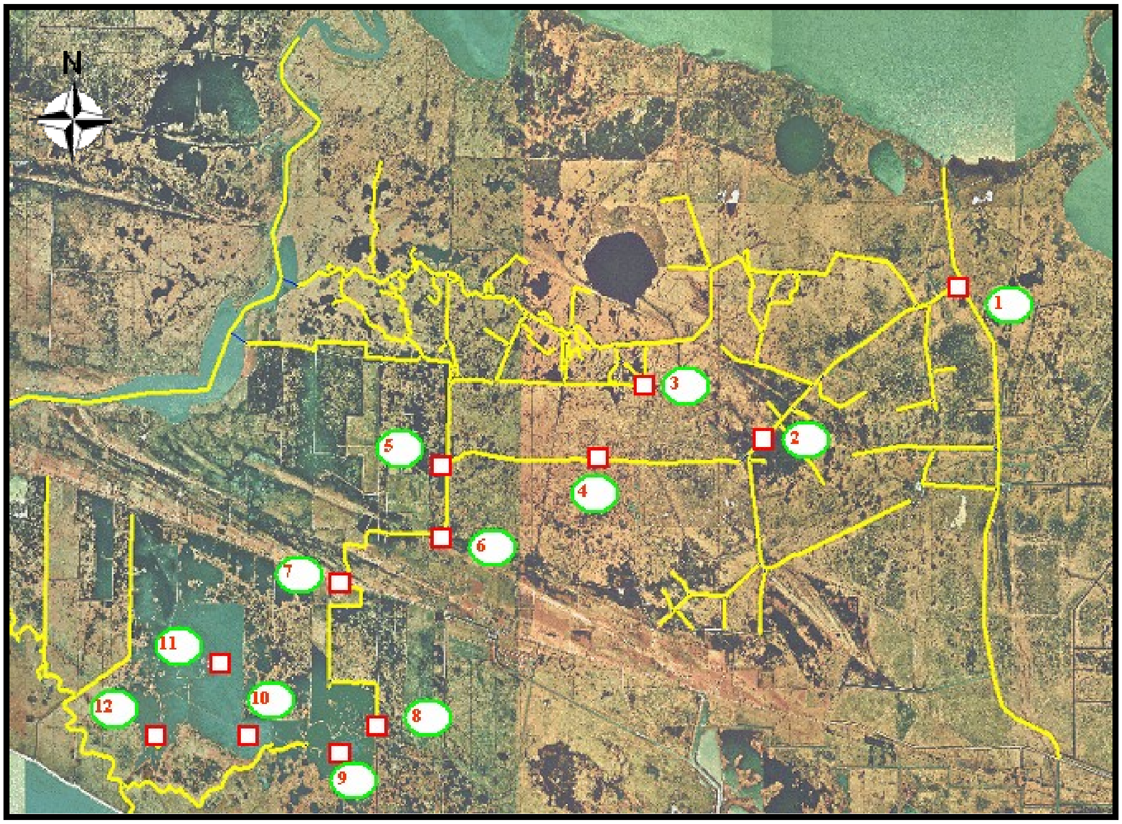


Figure 51: Locations Of Points Used To Assess The Proposed Project Features

3.3.1 FINAL ANALYSIS FOR ALL ALTERNATIVE RUNS FOR THE MARSHES SOUTH OF LA HWY. 82

I. <u>Salinity</u>

Inspecting the model results for the open water bodies and marshes south of LA Hwy. 82 for both additional runs (Alignment No.1 and Alignment No.2) revealed a decrease in salinity. The magnitude of salinity decrease did not vary much from one run to another with an average decrease of 2.5-3.5 ppt for points 9 through 12 shown in Figure 51. It can also be noted that the levee breaches allowed a better spread of the incoming freshwater and thus enhanced the decrease in marsh salinity in the target areas. The contour maps revealed that once the proposed features are in place, it takes the freshwater a certain period of time to reach the surrounding marshes and reduce salinity (flushing period). This period depends primarily on the magnitude of the incoming freshwater flow and the salinity level in the target area, and also on the distance of the point being investigated from the opening of each of the alignments. The eastern portion of the project target area will experience decrease in salinity earlier than the western side due to the proximity to the freshwater conveyance channel. For the modeled period (November through March 2003), the period was in the range of 30-40 days.

II. Water Level

Inspecting the model results for the open water bodies south of Highway 82 for both additional runs (Alignment No.1 and Alignment No.2) revealed an increase in water level(similar to the salinity case). The magnitude of water level decrease did not vary much from one run to the other with an average increase of 0.2-0.3 ft for points 9 through 12 as shown in Figure 51.

3.4 FINAL CONCLUSIONS AND CLOSING REMARKS:

The modeling effort presented in this study is aimed to evaluate the performance of the proposed project features for Alignment No.1 and Alignment No. 2. The project features as proposed in the scope of services included channel enlargement and freshwater introduction structures to improve freshwater flows from Grand Lake to the south across LA Hwy. 82.

A coupled one and two-dimensional (MIKE FLOOD) computer model was used to perform the evaluation of the proposed project features. The model was able to capture water level and salinity variations in the channel (1-Dimension) along with variations in open water bodies (2-Dimension). The model was calibrated and then validated against field data for the time period extending from November 2002 till April 2003.

The overall conclusion of this study are summarized below:

Both Alignment No.1 and Alignment No.2 accomplished the anticipated results of providing freshwater from Grand Lake to the open water bodies south of LA Hwy. 82. The magnitude of change of the hydrodynamic properties of the marshes due to the new alignments were the same with a decrease in salinity in the magnitude of 2.5-3.5 ppt. and an increase in water level of a magnitude of 0.2-0.3 ft. It should be noted that the upgrades in the canals and channels have been incorporated in the model. It should also be noted that in the existing conditions, the channels along Alignment No. 1 and 2 are to a large extent disconnected and carry low to null flows. For the “with project” scenarios, these canals are dredged and used to convey freshwater to the target area. Thus an “increase” in water level is observed.